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THE EXTENT OF THE STARRY HEAVENS.

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From early times able astronomers have tried to gain some clear and definite idea of the extent of the starry heavens. It is probably not too much to say that this line of study has been, in all time, the one great theme for scholars in science in every clime. As knowledge has increased, the interest in the study of the stars has not diminished but it has quickened its energy so much, that the last thirty years has largely changed the methods of study and increased the extent of all the various branches of astronomy.

Although new fields have been opened and the facilities for investigation have been marvelously multiplied, in all directions, this one question of the size of the starry universe has held the chief place in the minds of the great scholars of the world. Not only they, but intelligent people everywhere are interested in the same thing. They not only want to know the facts about the nature and extent of the universe, but they are interested, in a general way, in the methods used by astronomers to obtain knowledge of the starry realms. It is the purpose of this article to give some of the ways which the astronomer employs in trying to find the limits of the universe and important physical facts nearly related thereto.

When one looks upward to the stars on any clear and moonless night, a countless number of shining points meets his gaze in almost every direction. Sometimes the thoughtful observer will pause a little, and try to take in the wonderful sight more fully, and attach to it the larger meaning that may thus be borne in upon his mind, by its extent, its beauty and its sublimity. Not satisfied with what the naked eye can see, he seeks the aid of the telescope, and, thousands of stars seen before are now replaced by millions of worlds whose variety, beauty and lofty grandeur give an impression of awe that lasts.

At such times it is easy for one to feel his own littleness as Job felt his, when the Almighty spoke to him from the whirlwind. In contrast with the largeness and the power he sees in everything

about him he is led to ask: Is this star-lighted canopy an endless thing, or is it limited? Is the stellar universe infinite in extent or has it finite and definite limits set somewhere in the regions of illimitable space? Or, to put it in another way: Is it possible by the study of the stars, to determine whether or not, this universe is a thing of time, having had an absolute beginning, and will have a definite end in time to come; or, is it infinite both in time and space?

Down to the present time neither philosophy nor science has yet given a definite and unequivocal answer to it.

Kant argued upon it better than any other philosopher, but he proved equally well that the universe is both limited *and* unlimited in extent,—two propositions, the one the contrary of the other, both of which he knew could not be true. His proof was negative but that kind of proof was the best that he could use in his time. Hamilton helped Kant's difficulty somewhat in pointing out the fact that we can neither conceive of infinite space, nor of space bounded, hence it is assumed, (possibly without warrant) that the question of the size and the duration of the universe is beyond the grasp of finite minds, and that no definite answer to it in this form can reasonably be expected. So far as we know modern philosophy has not carried the discussion further in any important particular.

Astronomy considers this question in a different way. Its data are facts derived from observation, generalization from facts, working theories from generalizations and, finally the discovery of laws in nature from inductive proofs in theory. On the other hand philosophy deals with pure reason, analogy and a general fitness of things in the order of nature.

For the same reason that Kant's logic failed, all science will fail to answer this question if a definite reply is demanded. Before the question of an absolute boundary of the universe in space and time, or its contrary, every method of inquiry now known to man is significantly powerless. Notwithstanding all this the astronomer is not discouraged. He still hopes, if time enough is given him, to get full information of all that lies within the range of the telescope, and so to learn the laws that govern the stars, and to trace nature's operations to their beginnings, when and where such a thing is possible.

This problem is a very different one from that which demands a definite boundary to the universe beyond which it shall be known that nothing can exist, or the contrary of it, which is the infinite universe.

The astronomer *can further say* that science furnishes arguments bearing on the question, that mainly point *one way* toward an answer that interests scholars very generally. We will try to give a few of the more important of these in logical order.

1. The universe is built on a plan the groundwork of which is that broad and beautiful band of stars which we call the Milky Way, or the Galaxy. It is so brilliant that any one can see it easily, on any clear and moonless night, and strong moonlight does not wholly obscure it from view.

2. This belt of stars is the fundamental plane in the structure of the universe which apparently divides it into two equal and similar halves, suggesting unity and sphericity in the form of the whole. In the direction of the Milky Way the stars are so thickly crowded together that it is impossible to count them satisfactorily even with the aid of the telescope. In some places the mingled starlight gives the appearance of clouds and the name star-clouds has come into use since the advent of stellar photography.

3. By 3400 actual counts of stars in all parts of the sky, Herschel found that the distribution was the same on both sides of the Milky Way; comparatively thin 90 degrees from the galaxy and gradually increasing as it was approached from either direction. By these counts the stars in the Milky Way are certainly thirty times as many, unit for unit in space, as those are which are farthest away from it. This fact indicates unity of form, and it led Herschel to believe that the universe is really globular in shape.

4. The next step in the investigation which has been taken recently is due to the spectroscope. It is in regard to the color of the stars. By careful examination with this modern instrument, it is found that the prevailing color of the stars in and about the Milky Way is blue, while those away from it, and in the thinner regions approaching its poles, are yellowish in hue. The meaning of this is not yet certain, but the fact is important in showing that color is a factor in the make-up of the great stellar system.

5. From the star counts and other observations it is probable that the universe is spheroidal in shape, and that the diameter in the direction of the Milky Way is 8 or 10 times as great as is the diameter in the direction of the poles. It is also probable that our Sun and its system of planets is near the center of this immense circle of stars which is probably in the shape of a ring, nearly as it appears to the naked eye.

6. It is also known that the number of the stars of each of the fainter magnitudes in all directions rapidly increase until the ninth is reached, after which there is a marked falling off. This is a fact that must be considered in connection with the size and the form of the universe, for we know that the brighter stars as a class must be nearer to us than the fainter ones, as a class, but this rule does not hold true at all in the case of the individual stars, for we know of certain faint stars that are comparatively near, while some of the very brightest ones are immeasureably far away. If the law of increase in the number of stars was the same down to the faintest ones visible in the telescope and so on *infinitely* as holds true from those of the first magnitude down to the ninth, starlight at midnight would be as brilliant as sunlight at noonday. On the contrary it is known that the total amount of starlight at night does not equal one thirty-seven-millionth part of the light of the Sun. This fact tends to a limited universe.

7. Before the extent of the universe can be known more definitely, the nature and distances of the stars must be studied more fully. The work on star distances has been pushed most vigorously because everything else so much depends upon it.

In 1901 astronomer Gill, of the Observatory at the Cape of Good Hope, South Africa, published results of attempts to measure the distances of Canopus and Rigel, the first the brightest star in the heavens but one; the second, the brilliant blue star in the constellation of Orion. This work was done with skill and refinement of instrument probably equal to any in the world. Astronomer Gill's conclusion is that their distances are so great that he can not measure them. That means that these two great suns are so far away in space that they must be, at least, thousands, if not tens of thousands, of times as large as our own Sun. If this be true of some of the brightest stars in the sky, what shall we say of the distances of the millions of faint ones that make up the great mass of the universe? For we know, as said before, that the faint stars, as a class, must be many times as far away as the bright stars, as a class, but this is not true in regard to particular stars.

8. The distances of about one hundred stars have been measured, and all are so far away that the astronomer has found it convenient to devise a new unit of measure for stellar distances. The mile is the unit of distance for measures on the Earth; for the planets the Sun's distance, 93,000,000 of miles is a unit, but for the stars a *light-year* is chosen as a unit. By a light-year is

meant the distance that light will travel in a year at the rate of 186,330 miles per second. This distance in miles is equal to 186,330 multiplied by 31,558,000 (the number of seconds in a year). That product is about 45,000,000,000.

In other words the light-year is 63,000 times the distance of the Earth from the Sun. It will be necessary to use this large stellar unit to comprehend further study of the *size* of the universe. If it is remembered that the Sun unit is 93,000,000 times the Earth unit, and that the star unit is 63,000 times the Sun unit, then our further illustrations will be easily understood.

8. The nearest fixed star is at a distance of more than four light-years. It is probable that there is no star but α Centauri nearer than a distance of six light-years. If then we have a radius of six light-years and draw a sphere around the Sun as a center, all that great space within the sphere would not probably contain more than two stars, our Sun and the nearest star, α Centauri.

Take a radius twice as long as the first, that would be twelve light-years in distance, and describe another sphere around the Sun as the center, this larger sphere, concentric with the first, will enclose only six stars more,—8 in all; a third radius of eighteen light-years, made in the same way, would include in all only about 27 stars, and the fourth sphere of twenty-four light-years would probably contain not more than 64 stars. Beyond the distance of twenty-four light-years not enough stars have been measured to continue the generalization further as to number of stars related to distance. Theoretically it seems probable, so far, that the number of the stars varies approximately as the cube of their distances from a center near the position of our Sun in the celestial sphere. If we call a radius of six light-years unity, the first sphere has one star besides our Sun, the second sphere with twice the radius contains 8 stars, the cube of the two; the third the cube of three or 27; the fourth the cube of four or 64. Speed on in our flight until we have reached the eighth sphere, or a distance of forty-eight light years, and we reach the north star, and we have left behind only 500 or 600 stars of the hundreds of millions that we must consider in estimating the size of the universe.

9. We have one more means of study for this great question which will aid us to go a little further. We must now consider what astronomers call the proper motions of the stars. We say, "fixed stars." The word "fixed" is a misnomer. Probably every star in the universe is in motion. It is a slow star that

moves only one mile in one second; some fly at the rate of 100 miles per second and possibly some with even greater velocity. Two stars are known whose proper motion is so great that they will make a complete circuit around the sky in respectively 160,000 and 180,000 years. Then by proper motion of the star, the astronomer means the angular motion which a star appears to make in moving around his point of observation. It is measured in seconds of arc, and not in miles, or light-years. If we are thinking of a straight ahead motion of a star, that is a different thing, and should not be confused with what we call the proper motion of a star. One astronomer calls right-line motion the star's speed which is reckoned in miles to distinguish it from proper motion which is always angular movement in degrees, minutes and seconds. Astronomers have studied the speed of the stars for years, and the results of their work agree well in making the average speed of the stars about 21 miles per second. The study of the proper motions of the stars has been prosecuted even longer and more generally than that of their speed, and the conclusion reached by this means, is, that the stars which have an apparent proper motion of ten seconds of arc in a hundred years must be not far from a distance of 180 light-years. Now if we apply the law of the cube for the number of stars related to distance, then we shall have reached the 30th sphere of light-year distance and would have included in the list only about 27,000 stars. We know that there are about 10,000 stars whose proper motion is as large as the ten seconds of arc, which we have made the basis of this calculation. Astronomers who have made a careful study of this part of our theme, have said, "On the whole, it seems likely that out to a distance of 300 or 400 light-years there is no marked inequality in star distribution." If then we could fly out into space at the rate of 186,000 miles per second and keep on our journey for 300 or 400 years, we probably would not have reached the beginning of the Milky Way! If we should go on, and on, and on, until we had reached a distance of 3,000 light-years, possibly, probably there we should begin to see a thinning of the stars ahead of us. Make the journey 10,000 light years long, we then might find ourselves nearly through the great ring of stars that we call the Milky Way, and the stars before us would probably have thinned out so much that the great mass of them would appear to have been left behind. Set a celestial stake as one point in an approximate boundary of the universe, retrace the flight to our Sun, go out in every other possible direction to a distance from 2,000 to 10,000

light-years and mark limits in a similar way: we then might have the approximate limits of the universe, as astronomers think of them. Not that all stars would be included within the limits supposed, for probably the outlying portions are very irregular, but that the great mass of them would be thus included, this is the best opinion we know of that modern astronomy holds on the problem of the size of the universe.

ARE THE PLANETS INHABITED?

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[Opinion of Camille Flammarion.]

The inhabitants of the Earth have at last begun to think of the heavens. Ceasing to live blind and estranged in their own sphere they are beginning to see that the world in which they live is a planet circulating round the Sun and that other sister planets have also their place in the solar system. Mars is now a subject of social conversation like politics or socialism. In America as well as in Europe, in Buenos Ayres, Mexico, Caracos, as well as in Paris, St. Petersburg, Budapest or Stockholm the latest telescopic investigations are talked about, and it is well known that this neighboring world is at this moment approaching the Earth, that astronomers have their eyes upon it and that they have recently noted there luminous projections of which they seek the explanation. We recollect that fifteen years ago the planet being then also pretty near us some straight lines which led to the idea of canals were discovered therein and the question was mooted of possible inhabitants of this land of the heavens and a future communication with them.

Questions, replies, discussion and curious confusions have ensued, but finally there is an interest in these lofty questions which transports us for an instant above the commonplaces of ordinary life and general information advances a little in the knowledge of

NOTE:—The question of the habitability of the planet Mars is being discussed by scientific and popular writers, in both continents, almost more than ever before. It has seemed fitting at this time to present the rather extreme views of the distinguished Camille Flammarion on this theme that they be more definitely known by our readers, especially since we have the best opportunity to do so that has ever come to us. Miss Rachel Challice, 53 Cromwell House, Queens Gate, S. W., London, is a gifted writer and a scholar of high rank from several European universities. She presents, in the accompanying article, the approved views of Flammarion on one of the most difficult and uncertain themes known to modern astronomy. Ed.

the universe, and that is the main point. This remarkable development of public interest is easily explained by the marvellous achievements of contemporaneous astronomy, and by the admirable accuracy of certain obtained results. Short of having a stone for a heart and a lump of fat for a brain, it would be difficult not to feel some emotion before the power of science. If we declare for example that we know the geographical position of Mars better than that of our own globe, the hearer or reader is at first inclined to scepticism. But if we show him either in an instrument or a drawing the snows of the north or south pole of Mars, he will acknowledge that it would be impossible to do as much with this world, and he will have evidence that we know these regions better than our own. That is one fact worthy of interest but we can go a little farther still.

It is not only the poles but all the surrounding districts which are better known in Mars than on Earth not only from a geographical point of view but from a meteorological one.

Thus for example we can almost constantly measure the extent of the polar snows and we find that they vary with the seasons.

We see the snows brightened and warmed by the Sun, melt very rapidly from night to night so to say in a summer twice as long as ours. The snows melt almost entirely and there only remains a little ice upon a point which we know and which represents the cold pole 340 kilometers from the geographical pole. None of these details are known about this world, and even the inhabitants of Mars may be ignorant of them themselves if they have not been able to reach their own poles. However as their sea is open there at the end of the summer they have better conditions for exploring their polar regions. We can also say that generally speaking the meteorology and the climatology of Mars are more fixed than those of this world. At the moment of reading these lines you do not know and nobody can tell you what the weather will be tomorrow, but we know almost certainly beforehand what the weather will be tomorrow, next week or month, or in such or such a country of Mars, for if it is not the winter time we know it will be fine. For in the equatorial regions and the regions round the poles there is never a cloud to be seen, so to speak, between the equinox of spring and the equinox of autumn. When we cannot make a drawing of Mars the hindrance is never due to the atmosphere of that planet, so pure and transparent, but to that of our own, which is so often thick or disturbed.

All the geographical configurations, seas, coasts, islands, pen-

insulas, mouths of rivers or canals are drawn with accuracy; we know in advance what district will appear in the lens of the telescope and the length of the rotation of the planet is known to the hundredth part of a second. This rotation is 24 hours, 37 minutes, 22 65/100 seconds. We also know that the year of Mars is 59,355,041 seconds that is to say 686 days, 23 hours, 30 minutes, 41 seconds. But as this world turns upon itself a little more slowly than ours its year has 668 days. In fact the calendar of the inhabitants of Mars is composed of two consecutive years of 668 days and a bis-sextile one of 669 days. As with us, there is not an exact number of days in the Martian year. They must have reformed the calendar several times without arriving at perfection. But it is to be hoped that they are not so stupid as we who call the seventh, eighth, ninth and tenth months of the year the ninth, tenth, eleventh and twelfth, and have no universal agreement in the question of dates,—Russia only arriving at the 1st of January when the rest of the civilized world is at the 13th—who have three kinds of days, the civil which commences at midnight, the astronomical which commences at midday and the nautical which commences the preceding midday, who have no exact time as it is counted from conventional meridians and who have not even been able to agree to start from one single meridian. Being therefore according to all probability more advanced than our own in its planetary age, the Martian humanity must be more reasonable and less hindered by the pettinesses of frontiers, dialects, custom-houses, national rivalries, etc. It has doubtless long ago formed but one single and united whole. With the exception of the canals the most interesting observation made upon this neighboring world, or rather the one which has been the object of most dissertations is certainly that of the luminous projections. It has been said that the projections are seen beyond the border of the disc. This is not correct—they are seen upon the line which separates the hemisphere lighted by the Sun from the hemisphere which is not lighted, the line called the terminator. They are only seen when the globe of Mars exhibits a sensible phase only along this line of the terminator. It is a slight excrescence, a slight undulation or elevation upon the terminator. The sight is not more extraordinary than that of the irregularities on the Moon's edge in certain phases, when the Sun illuminates either after its setting or before its rising the tops of the mountains whose bases are in shadow, and these tops sometimes appear upon the Moon like luminous points detached from the disc.

Imaginations somewhat fantastic have spoken in this respect of forests on fire and of signals made by the Martians. The possibility of the actual peopling of Mars by a human species more intelligent than our own is a natural conclusion from our observations.

One can also admit without scientific heresy that the canals of Mars may be rivers straightened for the express purpose of distributing water which has grown scarce upon the planet.

The astronomers who deny these possibilities show a singular poverty of imagination. But this is no reason on the other hand for thinking one sees nothing but traces of human action in this neighboring world. With several explanations of an observed phenomenon it is preferable to take the simplest. The case of the luminous projections upon the line of the terminator is sufficiently explained by the illumination by the sun of the mountain tops.

Doubt was cast upon this explanation by an astronomer who found the height of these luminous points was 60,000 mertes, 37½ miles. But I have made the calculation and I find it is only 4,500 metres, 2¾ miles. These mountains would therefore not be higher than Mont Blanc, and perhaps less. Let us note also that these luminous projections are seen almost each time that the planet returns to the same conditions of solar illumination in relation to the Earth—they were seen in 1890 and 1892 as well as in 1894. The regions in which they appear are a sort of an island called Noachis, another called Hesperia and a third called Tempe. According to all appearance there is snow there and these high mountains are covered with it. The epoch in which the inhabitants of Mars will be able to communicate with us has not yet arrived, or, may be, the epoch has gone by. All students of cosmology agree in presenting us this planet as anterior to ours since it is farther from the Sun; and as having passed more swiftly through the phases of its astral life since it is smaller and lighter. It is impossible for us to imagine what forms living beings have assumed there, but it is also impossible to maintain that the forces of nature which are the same as here and which exercise nearly the same conditions (atmosphere, climates, seasons, steam, etc.) have been rendered sterile by a perpetual miracle of annihilation, whilst the world overflows with life, and the generative capacity of organisms always greatly exceeds the actual number reproduced which survives. But whatever be the form of the Martian humanity, these brothers of the heavens must be our superiors for many reasons. The first is that it would be difficult for a human species to be inferior to our own since we know not

how to conduct ourselves, and three parts of our resources are employed in keeping soldiers. Europe alone spends eight milliards francs a year, or twenty-two millions francs to a day and as it cannot pay this expense by normal resources it makes loans and is actually indebted to the amount of 121 milliards. Without mentioning other matters this fact alone suffices to give an idea of our state of barbarism and stupidity.

The second reason is that progress is an absolute law which nothing can resist. If then the inhabitants of Mars had a modest commencement centuries have brought them to an age of reason, and their actual state may now represent what our humanity will be in several millions of years. A third circumstance in their favor is that they are better circumstanced than we are to free themselves quickly from the burden of matter. In this planet of Mars the density of a cubic metre of water, earth or anything else is only the seventeenth part of what it is here, and the weight is only 38/100. A kilogram transported to Mars would only weigh 376 grams there, and a man or woman weighing 70 kilos would only weigh 26 there. Moreover the years are nearly twice as long as upon our moving island. Finally the climatological conditions seem much more favorable there and these are all advantages on the side of the Martians.

If then they have had any idea of sending us signals it is not likely to be at the present time. There is no reason to think that it occurred to them at the same time as it did to us, or that they have waited for us. Perhaps they tried it two or three hundred thousand years ago, before man's appearance here, in the Stone Age. Perhaps even they addressed our planet in the time of the mammoth or the Hipparion or cave bear, the iguanodon and the dinosaurians. Perhaps they recommenced it only two or three thousand years ago. Having never received any sign of life they will have concluded that either there are no inhabitants of the Earth or that they occupy themselves with other things than the study of the universe and the search of eternal truths.

About fifty years ago the astronomer J. de Littrow, director of the Observatory of Vienna mooted the idea of trying to establish optical communication with the inhabitants of the Moon. A triangle traced upon the lunar surface in three luminous lines of 12 or 15 kilometres, (7 to 9 miles) would be visible from here by the aid of our telescopes. We even observe much smaller details, for instance the singular topographical designs noticed in the lunar circle to which the name of "Plato" has been given. Then a triangle, a square, a circle of this dimension constructed by us

upon a vast plain by the aid of luminous points, either during the day in reflecting the solar light, or during the night by the aid of electric light would be visible to the astronomers in the Moon if these astronomers exist, and if they have optical instruments equivalent to ours.

The consequence of the reasoning is most simple. If we observed upon the Moon a triangle correctly made we should think we had seen wrong, we should ask ourselves if the hazard of geological movements may have given birth to a regular geometrical figure. Doubtless we should end by admitting this exceptional possibility. But if all at once we saw the triangle changed into a square which three months later was replaced by a circle then we should logically admit that an intelligent effect proves an intelligent cause, and we should think with some reason that such figures reveal without doubt the existence of geometricians in this neighboring world. From thence to seek the "*raison d'etre*" of the formation of such drawings on the surface of the Moon, to ask ourselves why and to what end our unknown brothers make these figures, there is but one step, and that step is quickly made; would it not be to establish relations with us? The hypothesis is not absurd. It is uttered, it is discussed, it is rejected as arbitrary, it is defended as ingenious. And why not, after all why should not the inhabitants of the Moon be more curious than we, more intelligent, more lofty in their aspirations, less absorbed than we are in material matters? Why should they not have supposed that this world may be inhabited as well as theirs? And why should not these geometrical signs have been made to ask us if we exist? Moreover it would not be difficult to reply in the same way. We see a triangle, we reproduce it here. We see a circle, we imitate it here, and hence the establishment of a communication between Heaven and Earth for the first time since the commencement of the world.

Geometry being the same for the inhabitants of all worlds, two and two making four in all the regions of infinitude, and three angles of a triangle being everywhere equal to two right angles, the signals thus exchanged between the Earth and the Moon would not be as obscure as the heiroglyphics deciphered by Champollion and the communication established would become swift, regular and fruitful. Moreover the Moon is only two steps from here. Her distance of 96,000 leagues (240,000 English miles), is only equal to 30 times the diameter of the Earth. A telegraphic dispatch would arrive there in a second and a quarter, and light does not take more time to compass this distance.

The Moon is a celestial province united even by nature to our destinies. Up till now we have remarked nothing in the Moon which gives rise to the suspicion of a thinking humanity inhabiting this little celestial isle. Nevertheless the astronomers who especially observe our satellite, and who make an attentive and persevering study of its singular aspects, are generally of opinion that this planet is not so dead as it seems.

One must not forget that in the present state of optics it is difficult to practically apply to the study of the Moon a magnification above two thousand. To see this world two thousand times nearer than it is in the heavens is only to bring it to within forty-eight leagues. Now what can one distinguish at forty-eight leagues? An army in march? A great city? Perhaps—but it is very doubtful.

What is certain is that enigmatical variations are certainly made upon its surface notably in the arena of the circle of Plato to which we referred. What is also certain is that the lunar globe, forty-nine times smaller than the Earth and eighty times less heavy, exerts on its surface a gravitational force only one-sixth as strong as that which exists on the surface of our planet, so that an atmosphere analogous to that which we breathe would be six times more rarified and difficult to perceive from here. There is then nothing surprising in this world seeming so different from ours. Moreover, seen from a balloon only 4,000 or 5,000 metres high this world appears deserted, uninhabited and silent as an immense cemetery, and anyone from the Moon might well ask even from this little distance whether there are people in France or any noise in Paris.

The cold, dead aspect of our pale satellite was not very encouraging for the realization of the original project of the astronomer J. de Littrow, and soon forgetting our next neighbor the imagination of a few scientists flew as far as the planet Mars, which is never nearer than fourteen million leagues to us, but it is the best known of all the celestial worlds, and so much does it resemble our planet in many ways that we should scarcely feel strange if transported thither with our Penates. The aspect of Mars in fact consoles us a little for that of the Moon. One might really consider oneself in some terrestrial sphere. Continents, islands, coasts, peninsulas, gulfs, waters, clouds, rains, inundations, snows, seasons, winters and summers, springs and autumns, days and nights, mornings and evenings are all there the same as here.

The years are longer as I said, but the intensity of the seasons

is absolutely the same as with us, inclination of the axis being the same as ours.

The days are a little longer as the diurnal rotation of the planet is 24 hours 37 minutes 23 seconds; but as we see the difference is not great. And note that all this is known with precision—this diurnal rotation for example being determined to the tenth of a second. When on a beautiful starry night we examine this world under a telescope, when we see the polar snows, which melt at spring time, those finely defined continents, those long gulfed Mediterraneans, this eloquent and varied geographical configuration, one cannot but ask oneself if the Sun which lights this world like our own, does not also shed light on living beings, we ask if rains do not fertilize anything, if this atmosphere be not inhaled by beings, or if this world of Mars which turns with rapidity in space be like a train on a railway travelling empty, containing neither passengers nor goods.

The idea that this world of planets with which we circulate as it does, around the Sun not being inhabited by any creatures whatever is so inconsistent that we cannot grasp it. By what permanent miracle of sterilization can the forces of nature which act there like here remain eternally inactive and barren? One conceives then that the idea primarily proposed for the Moon can be applied to the planet Mars. The distance of this planet from us is so great that although it is far larger than the Moon in volume, it seems even in its nearest approach to us, sixty-three times smaller.

Nevertheless we see that a telescope only magnifying sixty-three times shows Mars at the dimension of the Moon seen by the naked eye; and that a magnification of 630 times gives it a diameter ten times larger than our satellite seen with the naked eye.

Only if it were ever attempted to put in practice any project for the communication between this world and ours the signals would have to be established on a much vaster scale. It would not be a question of triangles, squares and circles of some kilometres in size, but of figures more than a hundred kilometres large. Moreover it would always be on the hypotheses, (1) that there are inhabitants of Mars; (2) that these inhabitants understand astronomy; (3) that they have optical instruments analogous to ours; and (4) that they observe our planet with interest. This planet must be to them a star of first magnitude, the evening and morning star, the brightest star of their heavens. We are in fact the shepherd's star to them and their mythologies must have raised altars to us.

Is this quadruple hypothesis conceivable? If one put the question to the universal vote of the world, the reply would be doubtful. Without going far enough to ask the opinion of the natives of Central Africa, or the Isles of the Pacific Ocean, or even to address the majority of the European populations, it is pretty certain that most people do not know that this world is a planet and that the other planets are worlds.

And then there is the common sense, the vulgar common sense which reasons in accordance with the excellence of its education.

"We are," it says, "of course the most intelligent beings in creation. Why should other planets have the honor of being enriched with intellectual powers equal to our own? Ought we even to admit the possibility of the existence of men similar to us?"

Certainly it might be returned these most intelligent nations of the world hardly know how to conduct themselves; their intelligence is employed in ruining each other for individual profit, they are deaf and blind to the future, and that they number among them both robbers and assassins.

But apart from that it may be said we are certainly very superior beings, and it is not probable that the myriads of worlds gravitating in the immensity of space have produced intelligences equal to ours.

Why then should one seek to establish an optical correspondence with the planet Mars? If it be inhabited, its inhabitants would not be on our level—it is waste of trouble; for even if they saw our signals they would not understand that they are addressed to them. Thus we shall never begin.

But may not the inhabitants of Mars have already begun? According to geological computations the minimum age of the habitable world since the formations of the first spheres is twenty million years, seventeen hundred thousand for the primordal age, six million four hundred thousand for the primary age, two millio 1 three hundred thousand for the secondary age, four hundred and sixty thousand for the tertiary age, and a hundred thousand for the quarternary age. Man has only existed in this world for a hundred thousand years.

[TO BE CONCLUDED.]

SPECTROGRAPHIC INVESTIGATION OF THE ROTATION PERIOD OF VENUS.

PERCIVAL LOWELL.

In order to test spectrographically the rotation period of Venus, a spectrograph was ordered by this Observatory of Brashear in December, 1900. For the purpose in hand it was necessary that the instrument should be powerful, as the quantity to be measured was very small. The instrument was therefore made to be as efficient as possible. It was fitted with a diffraction grating and with a train of three prisms. The prisms justified the constructor's high opinion of them as is shown by the following tests.

Mr. Slipher has determined the efficiency of the prisms first for the question of dispersion and second for that of definition both of which are important in the measurement of the spectral lines. For a camera tube of 386mm in length, the one employed in these researches, he found the dispersion for the $H\gamma$ line to be 12.98 tenth-metres to the millimetre. This makes the dispersion of the train of prisms as compared with that of the Mills spectrograph and the Potsdam III spectrograph as follows:

Spectrographs.	Dispersion for one tenth metre.
Mills	40″.5
Potsdam III	39 .7
Lowell Observatory	41 .2

With regard to the definition he made tests on the close lines which could be separated on the photographs made of the solar spectrum with the results here given:

Spectr. Lines.	Δλ	Int.	Separation.
4058.915:	.166	3	Widely separated
4059.081:		3	
4076.644:	.148	2	Separated.
4076.792:		4	
4096.129:	.133	3	Separated
4096.262:	.105	2	Not separated
4096.367:		1	
4106.420:	.163	2	Widely separated
4106.583:		2	
4111.021:	.133	1	Just separated
4111.154:		1	
4122.673:	.146	3	Separated
4122.819:		1	
4134.494:	.095	3	Just separated
4134.589:		3	
4142.330:	.135	2	Just separated
4142.465:		2	
4142.629:	.115	2	Indication of separation
4142.744:		2	

Spectr. Lines.	Δλ	Int.	Separation.
4156.471:	.141	3	Separated
4156.612:		1	
4156.831:	.139	1	Separated
4156.970:		3	
4161.239:	.130	2	Well separated
4161.369:		2	
4171.068:	.145	4	Separated
4171.213:		4	
4229.926:	.149	3	Separated
4230.075:		1	
4235 298:	.152	2	Clearly separated
4235.450:		3	
4239.890:	.124	3	Clearly separated
4240.014:		3	
4395.201:	.212	3	Well separated
4395.413:		2	

For the Mills spectrograph Professor Campbell states: "In the solar spectrum, the limit of resolution with proper exposures on Eastman's lantern slide plates is about 0.15 t. m.; lines for which $\Delta\lambda = 0.20$ t. m. are rather widely separated."*

How much the excellent definition of these prisms is their own and how much the result of steady air is an interesting question. Unsteady air means that waves of condensation and rarefaction are passing rapidly between object-glass and object. These produce the effect of prisms rapidly interposed and as rapidly withdrawn beyond the end of the telescope. Thus spectral lines of different wave-lengths would be impressed with unequal duration and therefore give unequal intensities and unequal widths on the plate; secondly, different parts of the object would successively fall upon the slit and give wave-lengths affected by the motion of those parts; this is very important in a research like the present one. Both circumstances would give rise to more or less blurring. Whether the first be for much or little in the result, certain it is that the second must affect the result to a great extent and that consequently the situation of the Observatory was a favorable factor in the investigation. Its site being 7250 ft. or 2210 metres above the level of the sea the barometer stands at 23 inches instead of 30 and much of that objectionable bar to astronomic perfection, the atmosphere, is got rid of. The latitude 35° 11′ was also beneficial helping to raise the altitude of the planet and thus conduce to better definition. But the chief value of the site lies in the relatively steady character of the air for which quality it was originally selected. Though not so important spectroscopically as visually it is nevertheless a factor to be taken into account.

As to the advantages of the time chosen for the research in its

bearing on the result they are set forth by Mr. Slipher in his article as is also the manner an ingenious one in which he reduced systematic error to as nearly nul as possible.

Mr. Slipher was left entirely unbiassed in his investigation. In order furthermore to render himself unprejudiced in his measurements, in every case where he could have occasion to recognize or to think he recognized a plate, a paper covering up the plate number and bearing a fictitious number written without his knowledge by an assistant was put over the plate mark and was not removed until, not only the plate was measured, but practically the whole investigation closed.

His results follow. It is noteworthy that the value got with the slit parallel to the terminator is very nearly the value of the probable error in the investigation for the motion with the slit perpendicular to the terminator. This is of course what it should be as the probable error means that where no force is at work the result got would probably differ from zero by just this amount.

From the efficiency of the instrument and the unbiassed manner in which the measurements were made we may, I think, conclude from the size of the probable error that the evidence of the spectroscope is against rotation of short duration and that so far as its measure of precision permits the investigation confirms a rotation period of 225 days.

Astronomische Nachrichten, No. 3891.

COMPARISON STARS FOR THE ALGOL VARIABLE 4.1903.

MARY W. WHITNEY.

FOR POPULAR ASTRONOMY.

This interesting variable, discovered by Ceraski, is BD 73°.533. Its position for 1900 is

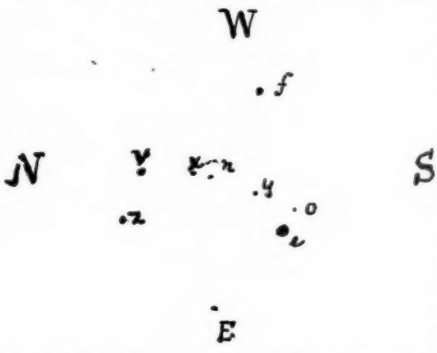
Right Ascension, $11^h\ 39^m\ 49^s$; Declination, $72°\ 49'.0$.

Its strikingly rapid changes have been recently followed at Vassar College Observatory, and several comparison stars in the neighborhood of the variable have been measured with a Rumford photometer. This form of wedge photometer is described by Mr. J. A. Parkhurst in the *Astrophysical Journal*, Vol. XIII, p. 249.

The grouping of the stars near the variable is shown in the accompanying figure. Their magnitudes are given in the following table:

	BD. °	BD. Mag.	Phot. Mag.
e	72.545	8.8	9.24
f	72.543	9.1	9.57
z	73.534	9.5	10.38
v	73.533	9.5	.....
x			11.44
y			12.42
o			12.70
n			13.10

These photometric magnitudes are based upon three Harvard Photometry stars situated in the immediate neighborhood. A provisional value of the photometer constant was used, as the final value has not yet been obtained.



f and *e* differ in right ascension $2^m\ 33^s$ and in declination 1′.6, by their BD. positions. *Z*'s declination is erroneously given in the *Durchmusterung* by about 2′.5, as noted by Ceraski; *x* is about 4′ south of *v*, and *y*, about 5′ south of *x*; *n* is about 1′ south of *x*. Another faint star lies near *y*. At maximum the variable is about two tenths of a magnitude fainter than *z*. It passes rapidly below *x* and with equal rapidity below *y*, reaching at minimum a magnitude closely equal to that of *n*. The period of 4.1903 as published by Professor Pickering is $1^d\ 8^h\ 34^m.7$. The minimum observed at Vassar occurred at $10^h\ 30^m$, July 26th.

THE SMALL TELESCOPE IN THE HIGH SCHOOL.

W. W. PAYNE.

We are often asked about small telescopes for the use of teachers of elementary astronomy in the high school, regarding cost, efficiency, makers and especially what such an instrument will enable an instructor to do for students in helping them to become familiar with the important features known to one of the most delightful studies in the whole range of science.

Such queries as these have led the writer to look over the schedules of studies largely in use in the high schools of the United States and he was greatly surprised to find that scarcely one-tenth of these schools are now giving any attention at all to elementary astronomy. School officers and some leading instructors do not seem to think that the study is a proper one for the high school. They claim that it ought to be pursued in college, and there only, where the supply of costly instruments will be found that are needful for the proper study of such a difficult branch of learning.

In pressing our inquiries further, it became evident that not a few prominent instructors are so poorly informed about the proper methods of giving instruction in elementary astronomy, that they could not defend their views very well, when they were asked to give reasons for them.

When it is noticed how large a place and how much time are given to laboratory work in the high schools for the elements of chemistry and physics, it is no wonder that other useful things must be neglected. The method of teaching these branches is right but the amount of work required is too great, if it is the aim of these schools to give high school students a general preparation in science that will serve in best ways for subsequent training, or even for practical business life.

This important feature of our educational work might be expanded indefinitely before turning away from it, but this is not the place to consider it further. It is rather our purpose now to speak of some of the useful and the practical things that may be done with and without the aid of the small telescope.

If teachers would only prepare themselves to do a little work with their students outside of the class-room in half-hour periods, if not more, they would soon find an interest and a thirst for knowledge in the minds of the young people of their care that would be stimulating in a high degree.

Speaking of this idea of carrying the study of elementary astronomy into evening exercises, before a company of experienced educators in kindred scientific lines, the question was asked, "How would you do work of that kind for students?" The answer was, "Just as you do with your laboratory work in physics and chemistry."

For naked-eye work, a teacher might try his class first on a lesson from the stars. Choosing the bright ones that have names—no matter if the names are long and difficult to pronounce, the young people will get them sooner than the instruc-

tor did, probably,—a dozen of them usually will be enough, and the class should practice on them, until they are perfectly familiar with them all and can write their names correctly and can locate them with reference to one another certainly. If a moonless night is near the writer would suggest another lesson on these same stars, before attention is drawn from them, that is the observation of their colors. This will furnish an exercise for closer and more careful observation. In this the teacher should be guided by approved astronomical authority on the colors of the stars chosen for this exercise. If an instructor should follow up this work for five such lessons of about twelve stars each, he would have quite finished the work of naming and color of all the stars in the heavens that are as bright as the first and second magnitude, and that would be more than any one person could see, unless he observed from some point on or near the terrestrial equator during at least the interval of about one year.

Of course this practice of naked-eye work on the stars might be continued in many different ways which we will not stop to specify now. We will only add that a text-book ought to be written for instructors bringing out graded and practical methods of studying the stars by naked-eye observation in which a great many young people could and probably would engage enthusiastically if the proper direction were given them. In the space at command we ought to say, also, something about the use of the small telescope in those high schools which can afford to purchase such an instrument.

After some preparation by naked-eye study of the stars, very great advantage will come to instructors and to classes who may avail themselves of the use of a small telescope, to carry observation a little further than it is possible to do without the aid of magnifying power.

Right at this point some school authorities have expended considerable money to obtain a telescope and its accessories which was larger than the real needs of the high school, and more expensive than could be wisely used, unless the teaching force is ample and the instructor in the elements of astronomy wishes to do some practical work of elementary kind involving the use of the spectroscope, the photographic camera and the micrometer. In such cases a driving clock and an equatorial mounting are desirable and quite necessary for satisfactory results. But we are now thinking of the wants and advantages of the average high school which could not and should not undertake this means of instruction for reasons already manifest to any intelligent reader of this account.

The question, then, very naturally arises, what can such a high school do and what should be advised about it? Very briefly this: For about $90.00 a thoroughly good 3-inch telescope with a tripod alt-azimuth mounting with three eye-pieces of appropriate powers can be secured from makers that are first-class in ability for both optical and mechanical work, and who are responsible in financial ways, so that a purchaser need fear no risk whatever in buying that kind of an instrument about which he himself may know very little and rightly hesitate to assume much responsibility. Right here we want to say, that the purchaser of a small telescope can not be too careful about selecting such an instrument. There are makers of small instruments in this country and abroad who advertise largely, but who turn out instruments, so-called, that are not worth the material wasted in making them. Never buy a small telescope without making some astronomer who is disinterested in the sale of the instrument responsible for testing it before purchase money is paid. Such a course will generally not add to the cost of the instrument, but, to our certain knowledge will save trouble and reasonably assure the purchaser of a good and safe bargain on his part.

If such an instrument is secured what can an instructor do with it? It may be said in a general way that an instructor provided with a good 3-inch telescope such as we have indicated, will have means of observation far beyond that which he will have time to use.

The most interesting work for first study will be the Moon. The gray plains or seas, so-called, the mountains, the great craters to the extent of 40 or 50 of the more prominent ones. If the student is required to note down carefully and in orderly manner all that he sees, and forms a habit of doing all his observing work in this way, it will certainly be time most profitably spent. But if he uses the telescope to simply look at the Moon, and to go over its surface rapidly and do no more than that, the benefit obtained will be small, for the impressions will soon fade from memory, as do the details of a novel that interest or please only for the time of reading.

The other themes that would occupy the attention in their time of appearance would be the planets, for they can all be seen with a telescope of 3-inches aperture, and a few of the asteroids, the brighter nebulæ, the stars studied by the naked-eye, reviewing especially their colors. If the telescope is well corrected for color, this study of the color of the stars will afford great satis-

faction; for in such a telescope the color of the stars will be more definite generally than that noted by the naked-eye. The reason for this is easy to see. The telescope shuts out of view almost all else but the star itself, it darkens the background of the sky and it diminishes the size of the spurious disc of the star, and yet the power of the eyepiece generally used on such a telescope is not so high as to make the star unsteady by the waves or tremors in the atmosphere. This work of color study is a very profitable one for a beginner to pursue. We can think of no way in which the color sense of young people can be exercised more effectively than in this.

Double and multiple stars open also a very wide field of observation. Since such stars usually have components that vary in color they offer a splendid opportunity to carry forward the work of star-colors. It will surprise students and instructors to learn something of the facts that appear in ordinary observation concerning the colors of these component stars. They will wish to know the reasons for the colors they see that suggest uniformity of plan, generally, but in some cases the conspicuous lack of it.

But one of the most interesting fields for the 3-inch telescope is the study of variable stars. This work is intensely interesting, and the student that once gets the visual taste of it, will often be ready and willing enough to go on with it, if he shall have opportunity to do so. This line of work comes the most quickly into that which is original and useful to the science of astronomy, of any other we know. More may be said of this at another time.

THE ASTROGRAPHIC CHART AND ASTROGRAPHIC METHODS.*

We measure the Earth at present as the Lilliputians measured Gulliver for a suit of clothes. Finding his bulk too huge for direct measurement, they took the girth of his thumb; and from experiments on their own bodies found the factor by which this should be multiplied to get the circumference of his waist and his other dimensions. India stretches about 20°—about one-eighteenth of the circumference of the Earth—in both directions; and, although this means a considerable Empire of which we may well be proud, it is unsatisfactory in determining the Earth's circumference to

* Extract from a lecture delivered by H. H. Turner, Savilian Professor of Astronomy, Oxford, England, at the School of Military Engineering, Chatham, Jan. 8, 1903.

have to multiply by eighteen. We must confess that existing surveys of our globe are distinctly "scrappy."

Until fifty years ago the same might have been said as to our survey of the heavens, and with much less excuse. Terrestrial surveys of the remote regions have been difficult and even impossible because of the dangers to life involved; but the heavens have been open to our scrutiny without any attendant risk except perhaps that of catching cold. There is, however, another reason for selection of special regions for survey which is common to both terrestrial and celestial enterprises, viz., some are more immediately *useful* than others. We need not stop to consider the earthly applications of this principle which are obvious enough; but as regards the heavens it may not be so well known that considerations of practical utility had a large share in directing observation. In the old days special attention was paid to the paths of the planets because there was a firm belief in their influence on human affairs. "The stars in their courses fought against Sisera;" and when such allies were liable to appear on one side or another, it was clearly important, even from a strictly military point of view, to be able to follow the evolutions of the celestial army. Coming nearer our own times, it is the needs of sailors rather than of soldiers which have dictated astronomical policy. Our own Royal Observatory at Greenwich was founded explicitly for observations of the Moon and fixed stars, in order that sailors might be the better able to determine their longitude at sea; and although the subsequent invention of the chronometer enabled a sailor to carry accurate Greenwich time to sea with him, whence he was enabled to infer his longitude without observing the Moon, the policy of observing the Moon as often as possible is still maintained at Greenwich; accordingly stars in or near the path of the Moon have been much better surveyed than the rest of the heavens.

If I may be pardoned for a small digression, I wonder how long it will be before the chronometer is in turn superseded by wireless telegraphic signals? If Mr. Marconi's claims are well founded, it should be possible to supply a ship, or a traveller, with Greenwich time during the whole voyage; and there should be no longer any difficulty at all in finding longitudes. Again we have been told that the chief difficulty in getting good forecasts for the British Isles is that our weather comes from the Atlantic where there is no observing station. But it seems possible that any ship crossing the ocean is a potential observing station henceforth, and our forecasts ought to become worth something. But how soon will it

be? Sometimes a long interval elapses between actual discovery and the utilization of it. In his life of Captain Cook, our present Hydrographer remarks that Captain Cook did not take with him on his first voyage round the world a single chronometer, although the invention had been made some time previously; he preferred apparently to trust to the old method of observing the Moon and took with him an astronomer for the purpose. And so although Mr. Marconi seems to have already rendered practical a simple means of determining longitudes, it may be many years before we see it actually employed.

But to return to surveys of the sky—the first step towards a complete survey of the sky (beyond the few thousand bright stars) was made about fifty years ago by a celebrated German called Argelander. This was before photography of stars had been rendered feasible, and his methods were most laborious, as we shall presently illustrate; but he and his hardworking assistants completed the work for the Northern hemisphere. They made a series of maps which would fit on to a celestial globe about seven feet in diameter—not a very large scale when we consider that our 1-mile to 1-inch maps correspond to a globe over 200 yards in diameter. Still Argelander's was a most useful work, and it has recently been extended to the Southern hemisphere by photography.

The project I have to speak of tonight is that of making by photography the equivalent of a celestial globe 50 feet in diameter, or what may be called on the analogy of terrestrial maps 14 miles to the inch. This is a notable advance on anything done before, though it still falls short of what we may hope to do in the future, even if we aim no higher than the counterpart of the terrestrial mile-to-an-inch map.

Before detailing the historical circumstances which led up to this project, I should like to say a word or two about the way in which astronomical photographs are taken. It is not necessary in these days to explain to anyone what a camera is. The camera of the astronomer, however, differs from the ordinary camera in practically two essential respects. First, the focal length is generally a good deal longer. If, for instance, I want to photograph an eclipse of the Sun, with an ordinary camera of (say) one foot focus, I should get a picture in which the obscuring Moon would be a black disc of only one-tenth of an inch in diameter, and round the edge would be seen, but on a very small scale, the beautiful corona which appears only on the occasion of a total eclipse. It is preferable to have a much larger photograph.

On the screen is shown* the long camera of 40 feet used by Mr. Michie Smith, the Government Astronomer of Madras, in photographing the eclipse of January, 1898, an occasion when I was also in India, photographing with another apparatus close by. On that occasion we were very kindly treated by the Royal Engineers who had charge of us—Major Burrard, Capt. Crosthwaite, and others. They cleared about a square mile of ground for us; they set up gorgeous tents, perhaps not equal to those used at the Durbar, but still very comfortable; they borrowed an elephant from a local Rajah for our use; and I believe they would have got a tiger for us to shoot, but they explained, rather apologetically, that the tigers were strictly preserved by "the Politicals." Mr. Michie Smith's camera is fitted at the top with apparatus for reflecting the Sun into it. The camera is not pointed directly at the Sun, but a mirror reflects a light down the camera to the dark room at the bottom, where the photograph is taken. The mirror is moved by clockwork, and that brings me to the second point wherein the camera of the astronomer differs from that ordinarily used. Either the camera itself must be pointed to the stars and moved by clockwork to follow their apparent movement, or a mirror must be moved so as to reflect the light constantly in one direction; otherwise the motion of the Earth would carry the celestial body across the sky and we should get a confused picture. On the screen is a potograph* of the region of the heavens near the North Pole, taken without clockwork. You see the Pole star has made a long streak of light, and similarly other stars at different distances from the center have made such streaks. There are a variety of instruments of the reflecting type for counteracting this motion. Some are called heliostats or siderostats; and another, which is called a coelostat, is particularly useful. On the other hand you may make the camera move itself as in the ordinary equatorial telescope, used for visual work. Indeed the camera is usually attached to a visual telescope through which the operator looks in order to keep one particular star steadily in view; for the clockwork is never quite perfect and a little final control by hand or from a pendulum is necessary.

And now I will say a word or two about how the particular project of making this map arose. The train of circumstances began with the appearance of the comet of 1882, which was the last great comet anyone in the Northern Hemisphere had a

* Not reproduced here.

chance to see, although one appeared recently in the Southern Hemisphere. (The one which appeared the other day did not count, for if any of you did see it you must have been disappointed.) The comet of 1882 was a very big one and stretched right across the sky. It was so fascinating an object that photographers tried to obtain pictures of it; but having only ordinary cameras, which are swept round by the Earth in its daily motion, they could not get any result of value. The Director of the Cape Observatory, Sir David Gill, invited Mr. Allis to strap his camera to the equatorial of the Observatory, which had clockwork for counteracting the Earth's motion; and some beautiful pictures were then obtained.

But is not the central feature of these pictures, the comet itself, which immediately concerns us. A quite unexpected result was the appearance of a vast number of stars on the plate as well, and Sir David Gill immediately thought, why not make maps of the heavens by photography? It was not entirely a new idea, but it was certainly new that so many stars could be obtained with such an exposure; and a great deal of this was due to the invention of the "dry plate," which was a great improvement on "wet plate" photography.

In order to show you what a great advance this was on the old visual method I will show on the screen* the way in which star maps had to be made before photography was used; how, for instance, Argelander observed the 200,000 stars to make his map which covered a globe seven feet in diameter; and how the map was made by the help of which the planet Neptune was discovered. About half-a-century ago the planet Neptune was discovered by mathematical analysis. Two mathematicians had satisfied themselves that a planet existed in a certain region of the heavens; but, since any one of about fifty stars in that region might be a planet, a star map of the region was necessary in order to identify the planet. * * * * * * * *

The little aperture represents about as much of the region as can be seen at once through a good visual telescope; and, owing to the motion of the Earth, if the telescope is kept fixed the stars will appear to travel across the small field of view. And so gradually one after another comes in, crosses this central wire and disappears on the other side. The moment of crossing the wire is noted and also the height at which it crosses. These two observations give us the position of the stars in the sky. In

* Not reproduced.

about twenty minutes the small aperture will have traversed the region represented on the screen, and we should get, perhaps, half a dozen stars recorded; and then we must begin again higher up or lower down. You can see how slow the old method was. By photography it would be but a matter of a few seconds to do all this with one exposure, and you can get some notion of the advance which has been rendered possible in making star maps.

Sir David Gill, as I have said, was struck with the idea of making a map of the stars by photography, and a similar idea had struck the Brothers Henry, of Paris, who were slowly and laboriously making a large scale map of a small portion of the heavens by old fashioned methods and, having almost come to a standstill at one portion thickly studded with stars, caught eagerly at the promises suggested by these comet pictures and tried whether photography would help them. The result was a very great success, though it was not attained without immense labor, skill, and the courageous support of Admiral Mouchez, the Director of the Paris Observatory, who made light of administrative difficulties. But when once satisfactory results were obtained, they were so completely successful that it seemed imperative to complete, not only the original project of the Brothers Henry, which included only a small portion of the heavens, but a map of the whole sky on the same scale.

For this, however, co-operation was necessary. To cover the whole sky with plates of the kind they were taking would require a total of 11,000 plates; and it was beyond the power of a single Observatory to obtain these in a reasonable time. Accordingly Admiral Mouchez and Sir David Gill called together an International Conference at Paris in April, 1887, which was attended by eminent astronomers from different countries as follows:—France twenty, British Empire eight, Germany six, Russia three, Holland three, U. S. America three, Austria two, Sweden two, Denmark two, Belgium one, Italy one, Spain one, Switzerland one, Portugal one, Brazil one, Argentine Rep. one. Many of the decisions of this Conference, arrived at after hard work and earnest discussion, and decisions which have had an important effect not only on this particular work but on the progress of astronomy generally, we have not the time to consider tonight. It must here be briefly stated that 18 observatories were chosen to share the work; that they were all to use a standard pattern of telescope, similar to that which the Brothers Henry had adopted (giving a scale of one minute of arc to a millimetre; or, in the terms already made use of, a celestial globe of 25 feet in di-

ameter); and that the sky was to be covered four times over, twice with plates of long exposure (originally defined as 20 minutes, subsequently extended to 40 minutes, and ultimately in some cases to an hour) and twice with plates of short exposure; thus giving about 1,200 plates of each exposure to each participating Observatory.

Our National Observatory at Greenwich, the University Observatory at Oxford, and the Observatories at Sydney, Cape of Good Hope and Melbourne were among those selected to take part in the work. Since the beginning of the project one or two of the Observatories have dropped out and Perth, in West Australia, has come in, so that altogether we are bearing a worthy share in the project. To give an idea of the size of the map (and I may say sheets of the map have already been published) it may be stated that when completed it will form a pile of paper 30 feet high, weighing about two tons. The question of storage will be a serious matter. With regard to the actual taking of the photographs there is not much to be said. Everyone in these days knows what taking a photograph means, and the taking of these particular photographs does not differ very much from the taking of others.

I think, however, it may be of interest if we turn to some of the results which we expect will accrue from this work, and which are already beginning to appear. In the first place one of the advantages of the survey is that we are to some extent enabled to detect new objects, new stars, or new planets. We shall also be able to compare the sky of the future with that of the present, and to see whether any new objects have appeared.

EROS AND THE SOLAR PARALLAX.

ARTHUR R. HINKS.*

The publications of the special committee appointed at the *Conférence Astrophotographique Internationale de Juillet*, 1900, to direct the coöperation in observing Eros for the solar parallax retain the name of "circulars," but have grown to monumental size. The first was of six pages, the fifth of fourteen, the seventh of sixty-seven, the ninth of two hundred, and the tenth, which has recently appeared, has two hundred and twenty pages of text, and ninety-eight of tables as an appendix. The aim of the committee is to bring together into one place and publish on a

* The *Observatory*, Sept. 1903.

uniform system the whole of the results from the coöperating observatories.

"Dans toutes les grands entreprises scientifiques réclamant de nombreuses collaborations, on s'est heurté toujours á de sérieuses difficultés. L'absence de coördination et d'homegénéite s'y faisait sentir, et surtout de grands retards, des lacunes même, dans la mise au jour des observations réduites, entravaient très souvent, d'une manière regrettable, les efforts des astronomes. On peut dire que jamais les théoriciens n'ont été mis à même de fonder leurs recherches sur des données directement comparables et complètes."

This is the difficulty which was greatly to be feared in the Eros work. To avoid it a magnificent effort is made, nominally by the Committee, practically, we may say without injustice, by its president, M. Loewy, on whom the great part of the work has fallen and to whom the credit is due. But we must not forget to acknowledge the liberality of the Academy of Sciences, which has taken upon itself the considerable expense of publication.

Let us glance at the different sections into which the work is divided. They are:

I. The determination with the meridian circle of the places of the "étoiles de repère," to be used as standards in the photographic reductions.

II. The determination by photography of the places of smaller stars to which the planet has been referred in visual observation with the heliometer and the filar micrometer.

III. The determination of the places of the planet on the photographs.

IV. The same from the visual observations.

Section I has been finished and published. Each coördinate of the "étoiles de repère" has been determined at some dozen observatories between twenty and thirty times in all, and the *individual means for each Observatory* are published, but no concluded mean which can be adopted as definitive. It appears to the writer that here a grave, perhaps a fundamental, mistake has been made. It is well known that right ascensions determined at different observatories differ systematically from one another by considerable quantities which are due, in great measure, to personal equation depending on magnitude. It might have been well to hand over the material to some man to be worked into shape, as Auwers worked up the similar material for Gill's heliometer observations of Victoria. At any rate some plain rule should have been made for the methods to be used in weighting

the individual results and taking the means. This criticism is based upon results appearing in Circular No. 10. The observatories of Paris and Bordeaux publish incidentally the places of the "étoiles de repère" which they have derived from the material given in former circulars. The difference Paris minus Bordeaux is almost uniformly positive; its mean value for 46 stars $+ 0^s.0062$, which in decl. $+ 54°$ amounts to $+ 0''.06$. No information is given as to the method of forming the means. The writer has used in the Cambridge reductions a weighted mean. A similar comparison with Paris gives for the mean difference Paris minus Cambridge for 43 stars the value $+ 0''.04$. It is clear that the right ascensions from some observatories are systematically different from the rest, and that the method of taking the definitive mean makes a difference which cannot possibly be neglected, if the solar parallax is to be derived from *absolute places* of the planet thus derived from the photographs.

Our Section II is concerned with finding the places of stars lying along the trajectory of the planet, to which it has been referred micrometrically. Elaborate arrangements were made to determine these places. A special series of 99 plates was in the programme carried out by several observatories; and all stars down to mag. 12 were to be measured which lay within the zone of $10'$ on each side of the planet's path. Further, on all the plates containing the planet, all stars visible within a square of $20'$ on the side around the planet were to be measured. When it appeared impossible in all cases to carry out this large programme in full, a list was published of the approximate places of such stars as had actually been employed, according to the reports of the observers, and to these stars special attention was directed, though the full programme was recommended to all who had the means to carry it out. This scheme appeared to be thorough, if perhaps excessive, and it was hoped that there would be no difficulty in providing thus for the reduction of all the micrometric measures. An examination of all the published measures is in this respect disappointing. The results published by the Paris Observatory cover the period of micrometric observations from 1900, Oct. 23 to Nov. 15, and they evidently contain, though the fact is not stated, the measures made upon the special series as well as in the square around the planet on the ordinary plates; that is to say, they should include all the stars down to mag. 12 and many down to 12.5 mag., which could by any possibility have been used as comparison stars. The writer has examined the measures made with the great equatorials of Washington, Lick and

Yerkes, and attempted to identify the comparison stars used, with the following result:—

	Stars whose places have been determined at Paris.	Stars whose places remain unknown.
Washington	17	26
Lick	17	13
Yerkes	33	22
	67	61

It appears that unless other observatories have been able to measure fainter stars than Paris has done, nearly one-half the results from these American observatories are useless, at least for the present. The reason for this is not altogether clear, but it seems to depend very much upon the fact that the Paris scale of photographic magnitudes differs from that in use with the large visual refractors, sometimes by as much as two magnitudes. It is, moreover, evident, on examining the lists, that some observers did not send to Paris the places of stars they had used, as they were asked to do. We must reluctantly admit that the arrangements made for the photographers to lend a hand to the visual observers have partly broken down; and there is much heavy work in store for somebody before the defect can be made good.

And there is another aspect of this case. The "étoiles de repère" were selected for plates taken with the standard astrographic telescope, with field 2° square, and they are frequently well distributed towards the edges of those plates. Not more than half of them are to be found on the plates taken with some of the other photographic telescopes employed, the Thompson 26″ at Greenwich, the Cambridge photographic equatorial, or that at Minneapolis. Not one quarter are in the measurable part of the thousands of exposures made with the Crossley reflector at Lick. Neither do these instruments show more than a fraction of the faint stars near the planet with which we have been dealing above—the exposures given were too short. There is need of a third set of standard stars, intermediate between the "étoiles de repère" and the "étoiles de comparaison," and for these no general provision has yet been made.

And now for third division, the deduction of the places of Eros from the photographs. Shall the measured rectangular coördinates of the photographs be laboriously turned into differences of right ascension and declination, the necessary corrections applied and the final result emerge as an absolute place of the planet? This is the procedure which is advocated by the Eros Committee.

It is no secret that it is not the plan which, as the writer believes, commends itself to other participators in the work besides himself. Consider, in the light of what has been pointed out above, what will be the position of a man who attempts to derive the solar parallax from absolute places of Eros as published by the observatories of Paris and Bordeaux. He will find that there is a systematic discordance between those places of about 0″.06 in right ascension, quite fatal except in special circumstances to a derivation of parallax. He will want to go below the surface, into the depths of the reductions, and bring into accordance the fundamental data, the places of the "étoiles de repère," and until all the data for every plate are published this will be impossible. When that is done, the now published absolute places may turn out to be superfluous, because affected by systematic error. It appears to the writer that the derivation of absolute places at this stage of the work is to be deprecated; that the form in which measures should be published at first is the raw measured rectangular coördinates of the planet and ten or a dozen comparison stars; that eventually someone will have to take in hand the formation of a definitive system of comparison stars (including repère stars), to which each set of raw measures can be finally and definitely reduced; and that then, if at all, the absolute places of the planet should appear. But in putting forward these criticisms he is anxious above all things to express at the same time his admiration for the vastly important work which has been done in collecting in the circulars of the Paris Conference all the information, exhortation, and advice to which M. Loewy has so unsparingly devoted himself, in order to hasten the time when "les savants disposeront ainsi pour la détermination de la parallaxe d'un ensemble de résultats d'une richesse dont on ne saurait trouver l'équivalent à aucune époque du passé."

THE ROTATION PERIOD OF SATURN.

H. C. WILSON.

The planet Saturn seldom exhibits definite markings upon its surface of such a nature as to permit of their use in determining the rotation period of the planet. Usually there are several zones of different shading somewhat similar to those upon Jupiter, but much less distinct and without any conspicuous spots which can be identified at successive rotations of the planet. In

the winter of 1876-77 Professor Asaph Hall, then working with the 26-inch telescope of the United States Naval Observatory, discovered a bright white spot in the equatorial belt of Saturn which could be recognized for several weeks. From a discussion of the observations of this spot he determined the rotation period to be $10^h\ 14^m\ 23^s.8 \pm 2^s.30$.

Other observers have since that time noted the transits of less conspicuous spots in the equatorial belt, which gave nearly the same rotation period, perhaps shortening it a little.

On the morning of June 16, at 3^h A. M. Central Standard Time, Professor E. E. Barnard, examining Saturn with the 40-inch telescope of the Yerkes Observatory, noticed a decided bright spot on the planet, half way from the central meridian to the following limb. On the morning of June 24 he again noticed a conspicuous white spot on the northern hemisphere of the planet and measured its position, when in transit, to be $2''.75$ north of the center of the planet's disk. Announcement was immediately made by telegraph to the principal observatories, so that within 48 hours astronomers all over the world were attempting to secure data for determining anew the rotation period of the planet. It is too early yet for all of the observations to be published and the collection of data here given will serve only for a preliminary determination of the period.

Several of the observers have observed two or more different spots but all in nearly the same latitude, in the light shaded belt just north of the dark belt on the northern hemisphere of the planet. In most cases these other spots were described as being less conspicuous and more diffuse than that discovered by Barard. Several describe the spot as double and brighter in one portion than in the other. This may account for some of the large discrepancies in the observed times of the central transits.

A least square solution of the equations formed from all the residuals which are under 20^m, after reduction for angle from the Sun and for distance, gives for the period $10^h\ 38^m\ 04^s.8$, but the final residuals are scarcely any better than those given in the table.

The different periods of rotation in different latitude imply that the surface which we see of Saturn, whether it be the actual surface or only that of an envelope of clouds, is not solid, but that as on Jupiter and the Sun the parts of the surface may move with different velocities. This has been inferred from our previous knowledge of the small density of the planet, but now is proved by actual observation.

The latitude of the center of Barnard's spot according to Mr. Barnard's observation of June 23 would be + 36°.4, assuming the equator of the planet to coincide with the plane of the rings. By my own measure on July 1 it would be + 31°.1. The discrepancy is probably due to errors of the measures which were made under unfavorable conditions because of the low altitude of the planet.

OBSERVATIONS OF WHITE SPOTS ON SATURN.

Observer.	1903.	Local or Standard Time. h m		Greenwich M. T. h m	Rotations.	Computed Time. P=10h 38m h m	Residual O—C. h m	Reference.
Barnard	June 15	15 0	C	22 20±	— 18	22 18	+ 2±	AJ 542
"	23	15 42	C	21 42	0	21 42	0	AJ 542
"	24	12 58	C	18 58	2	18 58	0	AJ 542
Hartwig	26	14 20	B	13 36	6	13 30	+ 6	AN 3881
Messow & Mainka	26	14 18	H	13 38	6	13 30	+ 8	AN 3883
Solá	26	13 19	G	13 19	6	13 30	— 11	AN 3894
Solá	July 1	13 55	G	13 55	17	10 28	+ 3 27	AN 3894
Denning	1	14 1±	G	14 1±	17	10 28	+ 3 33	Na 1758
Wilson	1	15 18	C	21 18	18	21 06	+ 12	PA 107
Graff	4	13 59	H	13 19	24	12 54	+ 25	AN 3883
Solá	8	12 40±	G	12 40±	33	12 36	+ 4±	AN 3894
Solá	9	10 00±	G	10 00±	35	9 52	+ 8±	AN 3894
Denning	9	14 04	G	14 04	35	9 52	+ 4 12	Na 1759
Solá	11	11 45	G	11 45			— 3 17	AN 3894
Solá	11	14 45±	G	14 45±	40	15 02	— 17±	AN 3894
Fauth	11	16 10	M	15 10	40	15 02	+ 8	AN 3888
Brenner	12	13 18	M	12 18	42	12 18	— 0	AR 47
Denning	12	12 50	G	12 50	42	12 18	+ 32	AN 3900
Phillips	12	12 30	G	12 30	42	12 18	+ 12	AN 3900
Kibbler	12	12 30	G	12 30	42	12 18	+ 12	AN 3900
Solá	14	11 15	G	11 15	46	6 52	+ 4 23	AN 3894
Brenner	15	11 34	M	10 34	49	14 44	— 4 10	AR 47
Denning	16	11 52	G	11 52	51	12 00	— 8	AN 3900
Brenner	16	13 00	M	12 00	51	12 00	— 0	AR 47
Brenner	17	10 16	M	9 16	53	9 16	— 0	AR 47
Solá	20	11 32	G	11 32	60	11 42	— 0	AN 3894
Solá	21	9 45±	G	9 45±	62	8 59	+ 46±	AN 3894
Solá	24	11 25	G	11 25	69	11 24	+ 1	AN 3894
Denning	24	11 17	G	11 17	69	11 24	— 7	AN 3900
Williams	24	11 34	G	11 34	69	11 24	+ 10	AN 3900
Solá	28	11 15	G	11 15	78	11 06	+ 9	AN 3894
Williams	31	13 20	G	13 20	85	13 32	— 12	AN 3900
Phillips	Aug. 4	13 5	G	13 05	94	13 15	— 10	AN 3900
Brenner	5	11 30	M	10 30	96	10 30	— 0	AR 47
Denning	5	10 20	G	10 20	96	10 30	— 10	AN 3900
		10 31	G	10 31			+ 1	
Phillips	5	10 40	G	10 40	96	10 30	+ 10	AN 3900
Williams	13	10 14	G	10 14	114	9 56	+ 18	AN 3900
Denning	25	9 12	G	9 12	141	9 02	+ 10	AN 3900
Denning	29	8 37	G	8 37	150	8 44	— 7	AN 3900

AJ = Astronomical Journal; AN = Astronomische Nachrichten; AR = Astronomische Rundschau; PA = Popular Astronomy. B = Bamberg M. T.; C = Central Standard Time; G = Greenwich M. T.; H = Hamburg M. T.; M = Middle Europe Time; Na = Nature.

For the observation of Barnard on June 15, I have added as a

rough approximation $1^h\ 20^m$ or ⅛ of the period in order to get the time of transit. It falls in extremely well with the other observations.

If we should consider the spot observed by Denning and Solá on July 1 to be identical with that observed by Denning July 9, and by Solá July 14, the period from this spot would be about $10^h\ 40^m$.

JOSIAH WILLARD GIBBS.*

It his last work, "Elementary Principles in Statistical Mechanics," Professor Gibbs returned to a theme closely connected with the subjects of his earliest publications. In these he had been concerned with the development of the consequences of the laws of thermodynamics which are accepted as given by experience; in this empirical form of the science, heat and mechanical energy are regarded as two distinct entities, mutually convertible of course with certain limitations, but essentially different in many important ways. In accordance with the strong tendency toward unification of causes, there have been many attempts to bring these two things under the same category; to show, in fact, that heat is nothing more than the purely mechanical energy of the minute particles of which all sensible matter is supposed to be made up, and that the extra-dynamical laws of heat are consequences of the immense number of independent mechanical systems in any body,—a number so great that, to human observation, only certain averages and most probable effects are perceptible. Yet in spite of dogmatic assertions, in many elementary books and popular expositions, that "heat is a mode of molecular motion," these attempts have not been entirely successful, and the failure has been signalized by Lord Kelvin as one of the clouds upon the history of science in the nineteenth century. Such investigations must deal with the mechanics of systems of an immense number of degrees of freedom and (since we are quite unable in our experiments to identify or follow individual particles), in order to compare the results of the dynamical reasoning with observation, the processes must be statistical in character. The difficulties of such processes have been pointed out more than once by Maxwell, who, in a passage which Professor Gibbs often quoted, says that serious errors have been

* An extract from a biographical sketch of Josiah Willard Gibbs, by Henry A. Bumstead in *American Journal of Science*, September 1903.

made in such inquiries by men whose competency in other branches of mathematics was unquestioned.

On account, then, of the difficulties of the subject and of the profound importance of results which can be reached by no other known method, it is of the utmost consequence that the principles and processes of statistical mechanics should be put upon a firm and certain foundation. That this has now been accomplished there can be no doubt, and there will be little excuse in the future for a repetition of the errors of which Maxwell speaks; moreover, theorems have been discovered and processes devised which will render easier the task of every future student of this subject, as the work of Lagrange did in the case of ordinary mechanics.

The greater part of the book is taken up with this general development of the subject without special reference to the problems of rational thermodynamics. At the end of the twelfth chapter the author has in his hands a far more perfect weapon for attacking such problems than any previous investigator has possessed, and its triumphant use in the last three chapters shows that such purely mechanical systems as he has been considering will exhibit to human perception, properties in all respects analogous to those which we actually meet with in thermodynamics. No one can understandingly read the thirteenth chapter without the keenest delight, as one after another of the familiar formulæ of thermodynamics appear almost spontaneously, as it seems, from the consideration of purely mechanical systems. But it is characteristic of the author that he should be more impressed with the limitations and imperfections of his work than with its successes; and he is careful to say (p. 166): "But it should be distinctly stated that, if the results obtained when the numbers of degrees of freedom are enormous coincide sensibly with the general laws of thermodynamics, however interesting and significant this coincidence may be, we are still far from having explained the phenomena of nature with respect to these laws. For, as compared with the case of nature, the systems which we have considered are of an ideal simplicity. Although our only assumption is that we are considering conservative systems of a finite number of degrees of freedom, it would seem that this is assuming far too much, so far as the bodies of nature are concerned. The phenomena of radiant heat, which certainly should not be neglected in any complete system of thermodynamics, and the electrical phenomena associated with the combination of atoms, seem to show that the hypothesis of a finite number of degrees of

freedom is inadequate for the explanation of the properties of bodies." While this is undoubtedly true, it should also be remembered that, in no department of physics, have the phenomena of nature been explained with the completeness that is here indicated as desirable. In the theories of electricity, of light, even in mechanics itself, only certain phenomena are considered which really never occur alone. In the present state of knowledge, such partial explanations are the best that can be got, and, in addition, the problem of rational thermodynamics has, historically, always been regarded in this way. In a matter of such difficulty no positive statement should be made, but it is the firm belief of the present writer that the problem, as it has always been understood, has been successfully solved in this work; and if this belief is correct, one of the great deficiencies in the scientific record of the nineteenth century has been supplied in the first year of the twentieth.

In method and results, this part of the work is more general than any preceding treatment of the subject; it is in no sense a treatise on the kinectic theory of gases, and the results obtained are not the properties of any one form of matter, but the general equations of thermodynamics which belong to all forms alike. This corresponds to the generality of the hypotheses in which nothing is assumed as to the mechanical nature of the systems considered, except that they are mechanical and obey Lagrange's or Hamilton's equations. In this respect it may be considered to have done for thermodynamics what Maxwell's treatise did for electromagnetism, and we may say (as Poincaire has said to Maxwell) that Gibbs has not sought to give a mechanical explanation of heat, but has limited his task to demonstrating that such an explanation is possible. And this achievement forms a fitting culmination of his life's work.

PLANET NOTES FOR NOVEMBER.

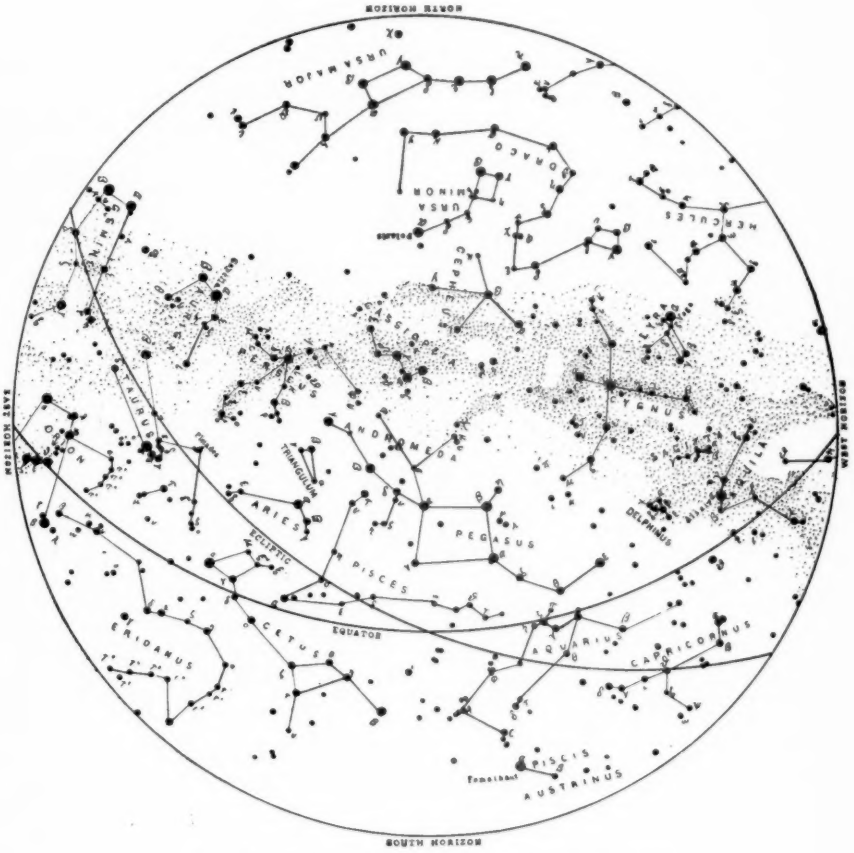
H. C. WILSON.

Mercury will be invisible to the naked eye during November, being at superior conjunction on the 21st.

Venus will be seen as the brilliant morning star toward the east during this month. Her greatest brilliancy is attained Oct. 24 but she will be at greatest elongation, west from the Sun 46° 46′, on Nov. 28. The phase, now crescent, will increase to half full at the end of the month.

Mars passes the meridian at about 3 o'clock in the afternoon and may be seen toward the southwest after sunset, but at so low an altitude that observations are practically useless.

Jupiter is at his best now for the amateur, coming to the meridian early in the evening, and at a fairly good altitude. When the seeing is good the wealth of detail shown in the ruddy belts of the planet by the aid of a good telescope is simply marvelous. The planet will reach the west end of the loop in his annual path on Nov. 9 and will after that time move eastward.



THE CONSTELLATIONS AT 9 P. M. NOVEMBER 1, 1903.

Saturn is a little too far to the west in the evening for the best seeing but may be observed in the twilight hours. The white spot discovered by Barnard is no longer conspicuous, if at all visible. The published observations of this spot seem to be best satisfied by a rotation period of $10^h\ 38^m$. Some of the observers have noted the transits of other fainter spots in the same zone, and these appear to indicate nearly the same period of rotation.

Uranus is too low in the southwest in the early evening for any satisfactory observations.

Neptune may be found at any time after midnight, in the constellation Gemini not far from the star μ.

The Moon.

Phases.		Rises. (Central Standard Time at Northfield Local Time 13m less.)	Sets.
		h m	h m
Nov. 4-5	Full Moon	5 00 P. M.	7 11 A. M.
11-12	Last Quarter	11 32 "	1 23 P. M.
18	New Moon	6 24 A. M.	4 47 "
26	First Quarter	12 30 P. M.	11 40 "

Occultations Visible at Washington.

Date. 1903.	Star's Name.	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle from N pt. °	Duration. h m
Nov. 2	73 Piscium	6.4	14 20	69	15 26	255	1 06
2	*e* Piscium	5.7	16 23	143	16 44	286	0 21
4	38 Arietis	5.2	11 24	65	12 48	255	1 24
6	75 Tauri	5.3	6 30	115	7 12	221	0 42
7	130 Tauri	5.5	16 51	145	17 37	222	0 46
11	*o* Leonis	3.8	15 34	77	16 40	321	1 06
26	ρ Aquarii	5.4	11 29	113	12 27	286	0 58
27	B.A.C. 8017	6.1	8 18	63	9 39	244	1 21
30	96 Piscium	6.6	10 52	78	12 09	240	1 17

COMET AND ASTEROID NOTES.

Ephemeris of Comet 1903 *c*.

[From A. N. 3896. Computed by Messrs. Dziewulski and Wagemann of Gottingen.]

Berlin Midn. 1903	R. A. h m s	Decl. ° ′	log *r*	log Δ	Brightness
Oct. 11	10 25 56	−32 44.4	0.0604	0.2080	0.4
13	27 56	34 41.3	0746	2129	0.3
15	29 57	36 35.7	0882	2178	0.3
17	31 56	38 27.9	1013	2229	0.3
19	33 55	40 17.7	1138	2279	0.3
21	35 53	42 5.3	1259	2330	0.2
23	37 49	43 50.7	1376	2382	0.2
25	39 43	45 34.0	1488	2434	0.2
27	41 35	47 15.1	1597	2486	0.2
29	43 24	48 54.2	1702	2539	0.2
31	45 9	50 31.3	1804	2592	0.2
Nov. 2	46 51	52 6.3	1903	2645	0.2
4	48 29	53 39.5	1998	2498	0.1
6	50 2	55 10.7	2091	2751	0.1
8	51 31	56 40.1	2182	2805	0.1
10	52 54	58 7.7	2270	2858	0.1
12	54 10	59 33.4	2355	2912	0.1
14	55 19	60 57.4	2438	2966	0.1
16	10 56 20	−62 19.8	0.2519	0.3020	0.1

Elements of D'Arrests' Comet.—In *Bulletin Astronomique* for Aug. 1903 Mr. G. Leveau gives new elements of this well-known periodic comet, brought up to date and corrected for the perturbations by major planets:

Epoch 1894 Dec. 31.0 Paris M. T.

$M = 231°\ 03'\ 11''.10$
$\pi = 319\ \ 26\ \ 19\ .58$ }
$\Omega = 146\ \ 25\ \ 11\ .02$ } 1900.0
$i = 15\ \ 42\ \ 31\ .70$ }
$\phi = 38\ \ 45\ \ 50\ .23$
$\mu = 530''.65339$

He gives also an ephemeris for the coming perihelion passage, which shows that the comet will be too nearly in line with the Sun, during the whole period of its approach, to be readily seen.

Search Ephemeris for Faye's Periodic Comet.

[From A. N. 3896 computed by Elis Stromgren, Kiel.]

1903.	Perihelion May 26. α	Perihelion May 26. δ	Perihelion 1903 June 3.64. α	Perihelion 1903 June 3.64. δ	Perihelion June 11. α	Perihelion June 11. δ
	h m s	° ′	h m s	° ′	h m s	° ′
Oct. 2	8 51 13	+8 26.0	8 43 40	+8 54.3	8 35 43	+9 23.6
6	8 57 59	7 45.6	50 32	8 13.4	42 44	8 42.2
10	9 04 29	7 05.2	8 57 09	7 32.5	49 27	8 00.7
14	10 42	6 24.9	9 03 28	6 51.6	8 55 52	7 19.2
18	16 39	5 44.9	09 31	6 11.0	9 01 59	6 37.9
22	22 19	5 05.3	15 15	5 30.7	07 48	5 56.9
26	27 42	4 26.2	20 41	4 50.7	13 18	5 16.5
30	9 32 47	+3 47.8	9 25 48	4 11.9	9 18 28	+4 36.7

Ephemeris of Brooks Comet for the Return 1903-04.

[Computed by P. Neugebauer, A. N. 3868. Continued from p. 349.]

Berlin Midn. 1903.	R. A. h	m	s	Decl. °	′	″	log r	log Δ
Nov. 1	21	23	5.33	−19	31	52.9		
2		24	26.75	19	21	1.4		
3		25	49.35	19	10	4.1	0.2964	0.20117
4		27	13.08	18	59	1.0		
5		28	37.93	18	47	52.2		
6		30	3.88	18	36	37.6		
7		31	30.89	18	25	17.4	0.2954	0.21081
8		32	58.93	18	13	51.5		
9		34	27.99	18	2	20.0		
10		35	58.05	17	50	42.9		
11		37	29.08	17	39	0.2	0.2945	0.22042
12		39	1.06	17	27	11.9		
13		40	33.98	17	15	18.0		
14		42	7.82	17	3	18.7		
15		43	42.55	16	51	13.9	0.2938	0.22994
16		45	18.16	16	39	3.7		
17		46	54.63	16	26	48.0		
18		48	31.93	16	14	27.0		
19		50	10.05	16	2	0.7	0.2932	0.23939
20		51	48.96	15	49	29.1		
21		53	28.65	15	36	52.3		
22		55	9.09	15	24	10.4		
23		56	50.26	15	11	23.5	0.2927	0.24875
24	21	58	32.14	14	58	31.5		
25	22	0	14.71	14	45	34.5		
26		1	57.95	14	32	32.7		
27		3	41.84	14	19	26.0	0.2923	0.25801
28		5	26.36	14	6	14.5		
29		7	11.48	13	52	58.2		
30	22	8	57.20	−13	39	37.3		

Search Ephemeris for Comet 1896 V (Giacobini.)

(Continued from p. 395).

Berlin M. T.	Assumed Per. Pass. June 6.5 α			δ		Assumed Per. Pass. June 22.5 α			δ		Assumed Per. Pass. July 8.5 α			δ	
	h	m	s	°	′	h	m	s	°	′	h	m	s	°	′
Sept. 30						4	5	48	+ 13	29.7					
Oct. 4	4	39	19	+ 13	2.3	4	6	9	+ 12	45.0	3	21	24	+ 11	58.3
8						4	5	47	+ 11	59.0					
12	4	39	13	+ 11	44.6	4	4	45	+ 11	12.2	3	18	44	+ 10	3.9
16						4	3	4	+ 10	24.9					
20	4	36	31	+ 10	24.8	4	0	49	+ 9	37.8	3	13	53	+ 8	10.5
24						3	58	3	+ 8	51.4					
28	4	31	33	+ 9	6.5	3	54	51	+ 8	6.5	3	7	40	+ 6	25.3
Nov. 1						3	51	18	+ 7	23.8					
5	4	24	46	+ 7	53.2	3	47	33	+ 6	43.7	3	1	2	+ 4	55.3
9						3	43	40	+ 6	7.0					
13	4	16	51	+ 6	48.8	3	39	46	+ 5	34.0	2	54	42	+ 3	44.4
17						3	35	56	+ 5	5.3					
21	4	8	34	+ 5	57.2	3	32	15	+ 4	40.9	2	49	27	+ 2	55.4
25						3	28	50	+ 4	21.2					
29	4	0	36	+ 5	19.9	3	25	44	+ 4	6.0	2	45	40	+ 2	28.2
Dec. 3						3	23	1	+ 3	55.4					
7	3	53	38	+ 4	57.2	3	20	42	+ 3	49.0	2	43	40	+ 2	21.1
11						3	18	49	+ 3	46.8					
15	3	48	12	+ 4	51.4	3	17	22	+ 3	48.2	2	43	22	+ 2	29.4

Elements of the Planets (488), (490), (492), (498).

(Calculated at the Computing Institute at Berlin.)

Mean Equinox 1902.0.

Planet	Ep. 1902	M °	′	″	ω °	′	″	Ω °	′	″
(488) JG	June 11.5 B	73	38	29.0	69	56	51.0	87	20	58.1
(489) JO	Nov. 3.5 B	144	14	4.8	42	45	39.6	173	8	15.4
(490) JP	Sept. 3.5 B	354	34	31.9	180	27	13.3	179	6	19.1
(492) JR	Sept. 4.0 B	12	56	28.0	287	25	17.9	47	8	20.9
(493) JS	Sept. 7.5 B	329	46	50 6	38	26	35.1	358	34	34.8
(494) JV	Nov. 27.5 B	143	9	5.4	209	59	47.9	38	56	58.8
(495) KG	Nov. 21.5 B	20	56	40.0	200	0	56.3	186	20	56.3
(496) KH	Nov. 21.5 B	331	47	44.7	240	35	0.6	206	38	0.0
(497) KJ	Nov. 4.5 B	20	53	34.8	358	54	7.4	6	55	7.2
(498) KU	Dec. 31.0 B	67	38	39.8	237	59	40.2	98	7	53.1

Planet.	i °	′	″	φ °	′	″	μ ″	log a
(488) JG	11	20	20.0	6	41	22.3	636.246	0.497588
(489) JO	7	10	1.0	5	11	38.5	954.004	0.380304
(490) JP	9	21	24.4	4	48	25.1	626.633	0.501996
(492) JR	1	39	30.8	10	34	19.0	649.105	0.491795
(493) JS	15	25	38.2	9	17	51.5	641.417	0.495244
(494) JV	7	10	5.4	3	47	1.1	688.103	0.474902
(495) KG	2	14	16.8	8	28	23.6	910.120	0.393938
(496) KH	3	37	9.8	4	15	29.6	1103.453	0.338168
(497) KJ	4	53	42.3	17	25	44.2	740.971	0.453470
(498) KU	9	29	44.2	12	26	2.4	827.986	0.421322

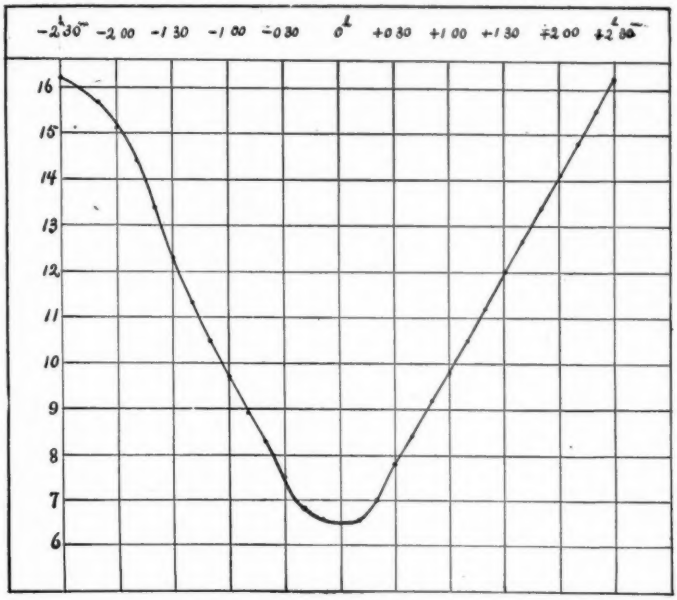
New Asteroids.—The following have been added to the list of minor planets since our last note:

	Discovered By	At	Local M. T.	h	m	R. A. h	m	Decl. °	′	Mag.
1903 LY	Wolf	Heidelberg	Aug. 24	10	40.0	23	16.1	+ 1	16	12
LZ	Wolf	"	Aug. 24	10	40.0	23	05.3	+ 1	26	13.5
MA	Dugan	"	Aug. 24	11	20.7	22	46.1	− 7	45	11.6
MB	Wolf	"	Aug. 24	10	40.9	22	59.9	− 0	28	12

VARIABLE STARS.

New Elements of the Variable U Ophiuchi.—In *A. N.* 3894 Mr. Luizet, of the Observatory at Lyon, gives a series of observations of this variable extending from July 1, 1898, to Aug. 23, 1902. From these together with the previously published observations of Chandler, Dunér, Sawyer, Schmidt and Yendell, Mr. Luizet has calculated the following new elements of the star, which satisfy the observations reasonably well:

$$\text{Min} = \text{J. D. } 2408368.5474 + 0.8386725E + 0.0090 \sin (0°.05143E + 77°)$$
$$= 1881 \text{ July } 17\ 15^h\ 33^m.3 \text{ (Paris M. T.)} + 20^h\ 7^m\ 41^s.304E + 13^m.0 \sin (0°.05143E + 77°).$$



LIGHT CURVE OF U OPHIUCHI.

The accompanying diagram gives the light curve of the variable constructed from Luizet's data. The following comparison stars are given for the scale of light:

*	BD. °	L.	*	BD. °	L.
a	−0.3224	19.5	*d*	+0.3629	12.7
b	−0.3230	14.4	*e*	+2.3283	9.0
c	−1.3292	14.0	*f*	+0.3654	4.5

The Variable Star 19.1903 Lyræ.—In *A. N.* 3898 Mr. R. S. Dugan gives a series of observations of this star on 27 photographic plates taken at Heidelberg in the years 1895-1903. Assuming Mr. Williams' period of $12^h\ 16^m\ 15^s.0$ as correct he deduces a light curve which is quite similar to that of Y Lyræ. The rise from minimum is very steep, being completed in one hour, while the fall is much slower, occupying six or seven hours. For the remaining four or five hours there is scarcely any perceptible change, the star remaining at about 11.2 magnitude.

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with midnight. The hours greater than 12 are those of the afternoon. To obtain Eastern Standard time subtract 5 hours; for Central Standard subtract 6 hours, etc.

U Cephei.

	d	h
Nov.	2	8
	4	19
	7	7
	9	19
	12	7
	14	19
	17	6
	19	18
	22	6
	24	18
	27	6
	29	18

Z Persei

Nov.	3	20
	6	22
	9	23
	13	0
	16	2
	19	3
	22	4
	25	6
	28	7

Algol.

Nov.	2	6
	5	3
	7	23
	10	20
	13	17
	16	14
	19	11
	22	7
	25	4
	28	1

λ Tauri.

Nov.	4	19
	8	18
	12	17
	16	15
	20	14
	24	13
	28	12

R Canis Maj.

Nov.	1	17
	2	20
	3	23
	5	3
	6	6
	7	9
	8	12
	9	16
	10	19
	11	22
	13	1
	14	5
	15	8
	16	11

R Canis Maj.

	d	h
Nov.	17	14
	18	18
	19	21
	21	0
	22	3
	23	7
	24	10
	25	13
	26	17
	27	20
	28	23
	30	2

RR (R^2) Puppis

	5	3
	11	13
	18	0
	24	10
	30	20

V Puppis.

Nov.	1	22
	3	9
	4	20
	6	7
	7	18
	9	5
	10	15
	12	2
	13	13
	15	0
	16	11
	17	22
	19	9
	20	20
	22	7
	23	18
	25	5
	26	15
	28	2
	29	13

S Cancri

Nov.	4	1
	13	13
	23	1

S Antliæ.

Period $7^h\ 46^m.8$

Nov.	1	19
	2	18
	3	17
	4	17
	5	16
	6	15
	7	15
	8	14
	9	13
	10	13

S Antliae

Period $7^h\ 46^m.8$

	d	h
Nov.	11	12
	12	11
	13	11
	14	10
	15	9
	16	9
	17	8
	18	7
	19	7
	20	6
	21	5
	22	5
	23	4
	24	3
	25	3
	26	2
	27	1
	28	1
	29	0
	29	23

S Velorum.

Nov.	3	0
	8	22
	14	20
	20	19
	26	17

U Coronæ.

Nov.	1	8
	4	19
	8	6
	11	17
	15	4
	18	15
	22	1
	25	12
	28	23

R Aræ.

Nov.	4	3
	9	14
	14	0
	18	10
	22	20
	27	6

Z Herculis.

Nov.	1	20
	3	18
	5	20
	7	18
	9	19
	11	18
	13	19
	15	18
	17	19
	19	17
	21	19

Z Herculis.

	d	h
Nov.	23	17
	25	19
	27	17
	29	18

RX (X^2) Herculis.

Nov.	1	7
	2	4
	3	1
	3	23
	4	20
	5	17
	6	15
	7	12
	8	9
	9	7
	10	4
	11	1
	11	23
	12	20
	13	17
	14	15
	15	12
	16	9
	17	7
	18	4
	19	1
	19	23
	20	20
	21	17
	22	15
	23	12
	24	9
	25	7
	26	4
	27	1
	27	23
	28	20
	29	17
	30	15

RV (V^2)Lyræ.

Nov.	2	16
	6	6
	9	20
	13	11
	17	1
	20	16
	24	6
	27	20

U Sagittæ.

	2	0
	4	9
	8	18
Nov.	12	3
	15	13
	18	22

U Sagittae.

	d	h
	22	7
	25	17
	29	1

SY (X^3) Cygni.

Nov.	3	22
	9	22
	15	22
	21	22
	27	22

SW (V^3) Cygni.

Nov.	1	2
	5	15
	10	5
	14	19
	19	9
	23	22
	28	12

UW (Z^4) Cygni.

Nov.	3	17
	7	3
	10	14
	14	1
	17	12
	20	23
	24	10
	27	20

W Delphini.

Nov.	1	2
	5	21
	10	16
	15	12
	20	7
	25	2
	29	22

Y Cygni

Nov.	1	12
	2	20
	4	12
	5	20
	7	12
	8	20
	10	12
	11	20
	13	12
	14	20
	16	12
	17	20
	19	12
	20	20
	22	11
	23	19
	25	11
	26	19
	28	11
	29	19

Variable Stars of Short Period not of the Algol Type.

	Minimum.	h	Maximum.	h		Minimum.	h	Maximum	h
T Vulpeculae	Oct. 16	5	Oct. 17	14	δ Cephei	Oct. 29	12	Oct. 31	3
β Lyrae	16	5	19	12	V Carinae	29	17	31	21
η Aquilae	16	7	17	13	T Velorum	30	7	31	16
V Carinae	16	8	18	12	W Sagittarii	30	12	Nov. 2	12
T Velorum	16	9	17	18	R Crucis	30	15	1	0
S Crucis	16	19	18	7	η Aquilae	30	15	1	21
TX Cygni	17	11	22	14	S Crucis	30	20	1	8
SU Cygni	17	14	18	22	S Triang. Austr.	31	5	2	7
U Aquilae	17	19	19	23	RV Scorpii	31	11	1	21
X Sagittarii	17	21	20	18	U Aquilae	31	20	3	0
T Monocerotis	18	6	26	4	V Velorum	31	21	1	20
S Trianguli Austr.	18	14	20	16	X Sagittarii	31	22	3	19
δ Cephei	18	18	20	9	V Centauri	Nov. 1	1	2	12
V Velorum	18	18	19	17	S Normae	1	4	5	14
T Crucis	18	21	20	22	TX Cygni	1	5	6	8
R Crucis	19	0	20	9	T Crucis	1	8	3	9
S Muscae	19	5	22	16	Y Sagittarii	1	8	3	3
RV Scorpii	19	8	20	18	SU Cygni	2	0	3	8
κ Pavonis	19	15	23	10	T Vulpeculae	2	22	4	7
W Geminorum	19	17	22	8	δ Cephei	3	21	5	12
S Sagittae	20	1	23	11	T Velorum	3	22	5	7
T Vulpeculae	20	15	22	0	W Geminorum	4	4	6	19
Y Sagittarii	20	19	22	14	U Sagittarii	4	7	7	6
T Velorum	21	0	22	9	β Lyrae	4	14	7	16
V Centauri	21	1	22	12	ζ Geminorum	4	19	9	19
U Vulpeculae	21	3	23	6	V Velorum	5	6	6	5
S Crucis	21	11	22	23	V Carinae	5	10	7	14
SU Cygni	21	11	22	19	R Crucis	5	11	6	20
U Sagittarii	21	19	24	18	S Crucis	5	13	7	1
S Normae	22	10	26	20	SU Cygni	5	20	7	4
β Lyrae	22	16	25	18	S Sagittae	5	20	9	6
W Sagittarii	22	22	25	22	U Vulpeculae	6	2	8	5
V Carinae	23	0	25	4	RV Scorpii	6	12	7	22
X Cygni	23	2	29	21	V Centauri	6	12	7	23
η Aquilae	23	11	25	17	S Triang. Austr.	6	13	8	15
δ Cephei	24	3	25	18	η Aquilæ	6	19	9	1
R Crucis	24	20	26	5	κ Pavonis	6	19	10	14
U Aquilae	24	20	27	0	Y Sagittarii	7	2	8	21
S Trianguli Austr.	24	22	27	0	W Sagittarii	7	2	10	2
X Sagittarii	24	22	27	19	T Vulpeculæ	7	9	8	18
T Vulpeculae	25	2	26	11	S Muscae	7	12	10	23
V Velorum	25	3	26	2	U Aquilae	7	21	10	1
SU Cygni	25	7	26	15	X Sagittarii	7	22	10	19
RV Scorpii	25	9	26	19	T Crucis	8	1	10	2
T Crucis	25	14	27	15	X Cygni	8	12	15	7
ζ Geminorum	25	15	30	15	T Velorum	8	13	9	22
T Velorum	25	16	27	1	S Crucis	9	5	10	17
S Crucis	26	4	27	16	δ Cephei	9	5	10	20
V Centauri	26	13	28	0	V Velorum	9	15	10	14
Y Sagittarii	26	13	28	8	SU Cygni	9	16	11	0
W Geminorum	27	10	30	1	S Normae	10	22	15	8
V Velorum	27	12	28	11	U Sagittarii	11	0	13	23
S Sagittae	28	10	31	20	β Lyræ	11	1	14	8
U Sagittarii	28	13	31	12	R Crucis	11	7	12	16
κ Pavonis	28	17	1	12	T Vulpeculae	11	19	13	4
S Muscae	28	20	Nov. 1	7	W Geminorum	11	22	14	13
β Lyrae	29	3	1	10	V Centauri	12	0	13	11
SU Cygni	29	3	Oct. 30	11	V Carinae	12	2	14	6
U Vulpeculae	29	3	31	6	W Virginis	12	2	20	7
T Vulpeculae	29	12	30	21	RV Scorpii	12	14	14	0

Variable Stars of Short Period not of the Algol Type.—Continued.

	Minimum.		Maximum.			Minimum.		Maximum.	
		h		h			h		h
S Triang. Austr.	Nov. 12	21	Nov. 14	23	U Vulpeculae	Nov. 22	1	Nov. 24	4
Y Sagittarii	12	21	14	16	W Sagittarii	22	7	25	7
T Velorum	13	5	14	14	T Velorum	22	12	23	21
SU Cygni	13	12	14	20	S Sagittae	22	14	26	0
S Crucis	13	22	15	10	V Velorum	22	17	23	16
V Velorum	13	23	14	22	R Crucis	22	22	24	7
η Aquilae	14	0	16	6	V Centauri	23	0	24	11
U Vulpeculae	14	2	16	5	S Crucis	23	9	24	21
S Sagittae	14	5	17	15	β Lyræ	23	23	27	6
T Monocerotis	14	7	22	5	RV Scorpii	24	17	26	3
δ Cephei	14	14	16	5	X Cygni	24	21	Dec. 1	16
W Sagittarii	14	17	22	5	κ Pavonis	24	23	Nov. 28	18
T Crucis	14	19	16	20	SU Cygni	25	1	26	9
X Sagittarii	14	22	17	19	ζ Geminorum	25	2	30	2
U Aquilae	14	21	17	1	T Vulpeculæ	25	3	26	12
ζ Geminorum	14	22	19	22	δ Cephei	25	8	26	23
κ Pavonis	15	21	19	16	S Trianguli Austr.	25	12	27	14
TX Cygni	15	22	21	1	V Carinae	25	12	27	16
T Vulpeculae	16	6	17	15	S Muscae	26	20	30	7
R Crucis	17	3	18	12	V Velorum	27	2	28	1
S Muscae	17	4	20	15	T Velorum	27	3	28	12
SU Cygni	17	8	18	16	W Geminorum	27	9	30	7
V Centauri	17	12	18	23	S Crucis	27	23	29	11
β Lyrae	17	12	20	14	T Crucis	28	6	30	7
U Sagittarii	17	19	20	18	η Aquilæ	28	8	30	14
T Velorum	17	23	19	8	V Centauri	28	12	29	23
V Velorum	18	8	19	7	SU Cygni	28	22	30	6
S Crucis	18	14	20	2	R Crucis	28	18	30	3
RV Scorpii	18	15	20	1	U Aquilae	28	22	Dec. 1	2
Y Sagittarii	18	16	20	11	X Sagittarii	28	23	1	20
V Carinae	18	19	20	23	W Virginis	29	9	7	9
S Triang. Austr.	19	5	21	7	T Vulpeculae	29	13	Nov. 30	22
W Geminorum	19	16	22	14	W Sagittarii	29	21	Dec. 2	21
δ Cephei	19	23	21	14	U Vulpeculae	30	1	2	4
T Vulpeculae	20	16	22	1	S Normae	30	10	4	20
S Normae	20	16	25	2	β Lyrae	30	10	3	12
η Aquilae	21	4	23	10	TX Cygni	30	16	5	19
SU Cygni	21	5	22	13	δ Cephei	30	17	2	8
T Crucis	21	12	23	13	RV Scorpii	30	18	1	4
U Aquilae	21	22	24	2	S Sagittae	30	23	4	9
X Sagittarii	21	23	24	20	S Triang. Austr.	31	20	3	22

Maxima and Minima of Long Period Variables.

[Computed from Chandler's "Third Catalogue." A question mark indicates that the elements are in doubt. By Misses Ida I. Watson and Helen M. Swartz of Vassar College Observatory.]

Maxima.

Date Nov.	No.	Star.
3	2478	R Lyncis
6	7907?	U Aquarii
7	6682	X Ophiuchi
11	5770	R Herculis
18	7192	Z Cygni
21	4596	U Virginis
22	678	U Persei
22	7085	RT Cygni
24	5070	Z Virginis
25	5338	U Bootis
26	7779	δ Cephei
27	8591	V Cephei

Maxima.

Date. Nov.	No.	Star.
28	1717	V Tauri
28	5617?	U Librae

Minima.

3	5157	S Bootis
9	5583	X Libiae
9	5955	R Draconis
11	2213	η Geminorum
11	2976	V Cancri
27	1805?	V Orionis
28	806	o Ceti
29	466	U Piscium

Approximate Magnitudes of Variable Stars Sept. 10, 1903.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R. A. 1900.		Decl. 1900.		Magn.
	h	m	°		h		h	m	°		h
T Androm.	0	17.2	+ 26	26	12*d*	R Camel.	14	25.1	+ 84	17	9*i*
T Cassiop.	0	17.8	+ 55	14	9*i*	R Bootis	14	32.8	+ 27	10	7*i*
R Androm.	0	18.8	+ 38	1	14*f*	S Librae	15	15.6	− 20	2	*s*
S Ceti	0	19.0	− 9	53	10*i*	S Serpentis	15	17.0	+ 14	40	9*d*
W Cassiop.	0	49.0	+ 58	1	*u*	S Coronae	15	17.3	+ 31	44	11*d*
S "	1	12.3	+ 72	5	10*d*	S Urs. Min.	15	33.4	+ 78	58	*f*
R Piscium	1	25.5	+ 2	22	9*i*	R Coronae	15	44.4	+ 28	28	6*d*
R Trianguli	1	31.0	+ 33	50	8*i*	V "	15	45.9	+ 39	52	*u*
U Persei	1	52.9	+ 54	20	8	R Serpentis	15	46.1	+ 15	26	9*d*
R Arietis	2	10.4	+ 24	36	12*d*	R Herculis	16	1.7	+ 18	38	14*f*
o Ceti	2	14.3	− 3	26	8*d*	R Scorpii	16	11.7	− 22	42	10*d*
S Persei	2	15.7	+ 58	8	9*d*	S "	16	11.7	− 22	39	13*f*
R Ceti	2	20.9	− 0	38	9*i*	U Herculis	16	21.4	+ 19	7	12*d*
U "	2	28.9	− 13	35	7*i*	R Ursae Min.	16	31.3	+ 72	28	*u*
R Persei	3	23.7	+ 35	20	*u*	W Herculis	16	31.7	+ 37	32	14*f*
R Tauri	4	22.8	+ 9	56	10	R Draconis	16	32.4	+ 66	58	10*d*
S "	4	23.7	+ 9	44	13*f*	S Herculis	16	47.4	+ 15	7	9*i*
R Aurigæ	5	9.2	+ 53	28	13*f*	R Ophiuchi	17	2.0	− 15	58	11*i*
U Orionis	5	49.9	+ 20	10	9*d*	T Herculis	18	5.3	+ 31	0	13*f*
R Lyncis	6	53.0	+ 55	28	8*i*	R Scuti	18	42.2	− 5	49	7*d*
R Gemin.	7	1.3	+ 22	52	7*i*	R Aquilae	19	1.6	+ 8	5	8*d*
S Canis Min.	7	27.3	+ 8	32	*f*	R Sagittarii	19	10.8	− 19	29	12*d*
R Cancri	8	11.0	+ 12	2	*u*	S "	19	13.6	− 19	12	*u*
V "	8	16.0	+ 17	36	*u*	R Cygni	19	34.1	+ 49	58	12*i*
S Hydrae	8	48.4	+ 3	27	*u*	RT "	19	40.8	+ 48	32	*u*
T "	8	50.8	− 8	46	*u*	X "	19	46.7	+ 32	40	11*i*
R Leo. Min.	9	39.6	+ 34	58	*u*	S Cygni	20	3.4	+ 57	42	10*i*
R Leonis	9	42.2	+ 11	54	*u*	RS "	20	9.8	+ 38	28	8
R Urs. Maj.	10	37.6	+ 69	18	8*i*	R Delphini	20	10.1	+ 8	47	11*i*
R Comae	11	59.1	+ 19	20	11*d*	U Cygni	20	16.5	+ 47	35	10*d*
T Virginis	12	9.5	− 5	29	*s*	V "	20	38.1	+ 47	47	14*f*
R Corvi	12	14.4	− 18	42	*s*	T Aquarii	20	44.7	− 5	31	10*d*
Y Virginis	12	28.7	− 3	52	*s*	R Vulpec.	20	59.9	+ 23	26	10*d*
T Urs. Maj.	12	31.8	+ 60	2	8*i*	T Cephei	21	8.2	+ 68	5	10*d*
R Virginis	12	33.4	+ 7	32	*s*	S "	21	36.5	+ 78	10	10*d*
S Urs. Maj.	12	39.6	+ 61	38	8*i*	S Lacertae	22	24.6	+ 39	48	*u*
U Virginis	12	46.0	+ 6	6	*s*	R "	22	38.8	+ 41	51	*u*
V "	13	22.6	− 2	39	*s*	S Aquarii	22	51.8	− 20	53	9*d*
R Hydrae	13	24.2	− 22	46	*s*	R Pegasi	23	1.6	+ 10	0	8*d*
S Virginis	13	27.8	− 6	41	*s*	S "	23	15.5	+ 8	22	12*i*
R Can. Ven.	13	44.6	+ 40	2	7*d*	R Aquarii	23	38.6	− 15	50	11
S Bootis	14	19.5	+ 54	16	12*i*	R Cassiop.	23	53.3	+ 50	50	10*i*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

Maxima of U Pegasi.

Period $4^h\ 29^m.8$. The minimum occurs $2^h\ 15^m$ after the maximum.

	d	h		d	h		d	h		d	h
Nov.	1	4	Nov.	9	0	Nov.	17	2	Nov.	25	3
	2	2		10	3		18	0		26	2
	3	1		11	2		19	3		27	0
	4	4		12	0		20	2		28	3
	5	2		13	3		21	0		29	2
	6	1		14	2		22	3		30	0
	7	4		15	0		23	2			
	8	2		16	3		24	0			

Maxima of UY Cygni.

Period $13^h\ 27^m\ 21^s$. The minimum occurs $1^h\ 53^m$ before the maximum.

	d	h		d	h		d	h		d	h
Nov.	1	1	Nov.	8	22	Nov.	16	18	Nov.	24	14
	2	4		10	1		17	21		25	17
	3	7		11	4		19	0		26	20
	4	10		12	6		20	3		27	23
	5	13		13	9		21	6		29	2
	6	16		14	12		22	9		30	5
	7	19		15	15		23	12			

Maxima of Y Lyræ.

Period $12^h\ 3.9^m$.

	d	h		d	h		d	h		d	h
Nov.	1	7	Nov.	10	8	Nov.	17	9	Nov.	24	10
	2	7		11	8		18	9		25	10
	3	7		12	8		19	9		26	10
	4	7		13	8		20	9		27	10
	5	7		14	8		21	9		28	10
	6	7		15	8		22	9		29	10
	8	7		16	9		23	9		30	10
	9	8									

The Period of the Variable Star 21.1903 Camelopardalis.—In *A. N.* 3894 Mr. S. Blajko gives the period of this star as $3^d.3056 = 3^d\ 7^k\ 20^m.1$. A minimum occurred July 20, the increase in brightness after the minimum being observed at Moscow from $10^h\ 14^m$ to $13^h\ 43^m$, Moscow M. T.

New Varible 31.1903 Herculis.—This is announced in *A. N.* 3894 and was discovered by Mme. Ceraski upon photographs taken by Mr. S. Blajko at Moscow. Its position is

1855.0	R. A. = $17^h\ 42^m.8$;	Decl. = $+ 22°\ 35'$
1900.0	$17\ 44\ .7$;	$+ 22\ 34$

and it varies from 10 to 11½ magnitude.

New Algol Type Variable 55.1903 Cygni.—This is announced by Mr. A. Stanley Williams in *A. N.* 3899. It is the star BD + 34°3938, R. A. = $20^h\ 09^m\ 36^s.9$, Decl. = + 34° 03′.7 (1855). Its normal brightness is about 9.8 magnitude and at minimum it descends to about 11.8. The increase and decrease each last for about $6^h\ 35^m$, and the star remains stationary in brightness at minimum for $6^h 20^m$ so that the whole duration of the change is about 19½ hours. The period is about $8^d\ 10^h\ 23^m$.

Mr. Williams gives the following elements and the Greenwich mean times of future minima for the remainder of the year:

$$\text{Minima} = 1903 \text{ Aug. } 21,\ 14^h\ 22^m \text{ Gr. M. T.} + 8^d\ 10^h\ 23^m\ E$$
$$= \text{J. D. } 24163485.985 + 8^d.4326E$$

Minima of 55.1903 Cygni.

	h	m		h	m		h	m
Oct. 2	18	17	Nov. 5	11	48	Dec. 9	5	20
11	4	39	13	22	11	17	15	43
19	15	2	22	8	34	26	2	06
28	1	25	30	18	57			

GENERAL NOTES.

Lowell Observatory Bulletins.—We are interested to see that Lowell Observatory has commenced the publication of Bulletins in quarto form, the same as Yerkes, Lick, Harvard Observatories and some others are doing. Bulletin No. 2 of Lowell Observatory contains an article entitled "Experiment on the visibility of fine lines in its bearing on the breadth of the 'Canals of Mars'."

Report of Astronomer at Cape of Good Hope gives several points of interest among which we notice the plan of placing meridian marks at long distances for the new transit circle, the spectroscope for radial work, the new objective of 24-inches aperture and the titles of recent publications, including the Cape catalogues of 8,560 astrographic stars. The showing is that of a busy, working Observatory.

Aberration of the Concave Grating when used as an objective spectroscope is the title of an important mathematical paper by F. L. O. Wadsworth, Director of the Allegheny Observatory which appears in the *Philosophical Magazine*, Vol. VI. 1903. Its results are very gratifying to those interested in this line of astronomical work.

The Cause of the Earth's Magnetism is the title of the leading article in the June number of *Terrestrial Magnetism and Atmospheric Electricity*, by William Sutherland, Melbourne. Australia. From this discussion, it would seem that there is not much doubt about the two distributions of electricity throughout the substance of the Earth. The author uses chemistry and mathematics in it effectively.

Poincaire's Review of Hilbert's Foundations of Geometry in the *Bulletin* of the American Mathematical Society is an elaborate paper which handles its theme in the clearest, best and most satisfactory way, generally, of any attempt of the kind we have seen from any other source. Students of pure mathematics will want to study that paper. It will bring them right into the van of the best mathematical thinking along its lines of the past as well as the present.

Washburn College Observatory, Topeka, Kansas, was dedicated September 18. The address, which will be published in the November number, was delivered by Professor Doolittle, of the Flower Observatory.

The equipment now comprises the 11½ inch "Grand Prix" refractor exhibited by Warner & Swasey at the Paris exhibition, a 5-inch photographic doublet, 7-centimeter combined transit and zenith telescope, sextant, mean time break-circuit chronometer, and a standard chronograph. There will be added at once a mean time and a sidereal clock, a position micrometer, a computing machine, and a working library of star charts and catalogues, tables, standard works of reference, and Observatory publications. Provision is also made for a meridian circle and spectroscopic outfit. The dome is a 26-foot, copper covered, by Warner & Swasey. There is a dark room, a clock and reception room, an apparatus room, library and computing room, and recitation room.

The Observatory is the gift of an eastern man who has not allowed his name to be announced in connection with the gift.

Retarded Motion of the Great Red Spot on Jupiter.—Perhaps the most notable fact brought to light by observations of Jupiter during the present season is that the velocity of the great red spot has been again retarded. The rotation period of this well-known object has been as follows in recent years:

	h	m	s		h	m	s
1898	9	55	41.8	1901	9	55	40.9
1899	9	55	41.9	1902 and to May 1903	9	55	39.0
1900	9	55	41.7	May 26 to Aug. 21, 1903.	9	55	41.5

At the end of May last the longitude of the spot was about 30°, whereas at the present time it is 32°, indicating an easterly drift of 2°, whereas during the preceding twelve months the marking had shown a westerly drift of about 1° per month. The spot now follows the zero meridian (system II of Mr. Crommelin's ephemeris, *Monthly Notices* R. A. S., LXIII, p. 110, December 1902) by about 53 minutes. A remarkable disturbance has recently occurred in the southern equatorial belt of Jupiter. In about longitude 140° to 175° (System I) several nearly black spots have appeared, and the belt in this region is much torn and full of irregularities, changing from night to night, and evidently subject to extensive commotions. W. F. DENNING.

The Spots on Saturn.—During the past two months about 75 transit times of these objects have been taken here. Several of the more conspicuous markings are moving slower than expected, and their positions appear to be well represented by a rotation period of about $10^h\ 39\frac{1}{2}^m$. W. F. DENNING.

BISHOPSTON, Bristol, August 25.

Dark Transit of Jupiter's Third Satellite.—The recent interesting discussions of Professor G. W. Hough and others appearing in POPULAR ASTRONOMY having re-enlisted my interest in Jovian phenomena, on the evening of August 16th I was examining the disk of Jupiter for details and while sweeping along her southern belt just east of the central meridian passage and just below the belt a faint darkish space was noted which rapidly increased in distinctness and at $12^h\ 22^m$ central time it equaled the average shadow of No. 2.

A peculiarity of this phenomenon was its rapid emergence into prominence and equally rapid decrease, it being too faint for detection until within 25 minutes of central meridian passage, and sank to invisibility 30 minutes before egress. In five previous observations of dark transits of this satellite I have been able to trace the dark planet very nearly from ingress to egress, the erratic appearance in this instance being an exception. WILLIS L. BARNES.

CHARLESTOWN, Ind.

Probable Value of the Solar Parallax.—T. J. J. See makes a brief statement in *A. N.* 3897 of the most probable value of the solar parallax.

He refers to the value of the parallax adopted in his papers since 1895 as

$$\pi = 8''.796 \pm 0''.006$$

and to that obtained by Professor Newcomb in 1897, as

$$\pi = 8''.7965 \pm 0''.0045$$

and also, to that of Boris Weinberg of the University of Odessa as

$$\pi = 8''.8004 \pm 0''.00243.$$

Dr. See calls attention to the fact that this last value does not seem to include the value which Professor C. L. Doolittle has recently obtained at the Flower

Observatory from determinations of the constant of aberration combined with the velocity of light. His aberration constant is 20″.530, which combined with the Michaelson-Newcomb velocity of light gave

$$\pi = 8''.777.$$

Professor A. Hall, Jr., from a discussion of Meridian Observations of Polaris in 1898 at Ann Arbor, Mich., found the aberration value to be 20″.55 corresponding to $\pi = 8''.769$.

More data will soon come from the extensive work on Eros that is still in process of reduction.

Mass of Mercury.—A value of the mass of Mercury, as deduced by Professor T. J. J. See from Hill's extension of the four inner planets of Laplace's law for the density of the Earth, with a correction to the mass of Mercury found by the same method in *A. N.* 3743. The value is approximately

$$\frac{1}{15{,}000{,}000}$$

That given by Professor Young in his Manual of Astronomy is

$$\frac{1}{7{,}000{,}000}$$

The large difference between these results shows the difficulty of obtaining the exact value of the mass of the planet.

Note on the Historical Sketch of Olaus Roemer.—Since writing the paper on Olaus Roemer published in POPULAR ASTRONOMY for May, I have had occasion to read Newton's *Optics*, edition of 1704, with more care than I had previously given to the subject; and I find after all that he did recognize the velocity of light in the first edition of that work. The absence of an index and the old form of printing make the finding of any given topic somewhat difficult. The following citations from Newton are of interest:

(1.) "Mathematicians usually consider the rays of light to be lines reaching from the luminous body to the body illuminated, and the refraction of those rays to be the bending or breaking of those lines in their passing out of one medium into another. And thus may rays and refractions be considered, if light be propagated in an instant. But by an argument taken from the equations of the times of the eclipses of Jupiter's satellites it seems that light is propagated in time, spending in its passage from the Sun to us about seven minutes of time: and therefore I have chosen to define rays and refractions in such general terms as may agree to light in both cases." —Def. II., Book I., *Optics*, p. 2.

(2.) "Light is propagated from luminous bodies in time, and spends abou seven or eight minutes of an hour in passing from the Sun to the Earth.

"This was observed first by Roemer, and then by others, by means of the eclipses of the satellites of Jupiter. For these eclipses, when the Earth is between the Sun and Jupiter, happen about seven or eight minutes sooner than they ought to do by the tables, and when the Earth is beyond the Sun they happen about seven or eight minutes later than they ought to do; the reason being, that the light of the satellites has farther to go in the latter case than in the former by the diameter of the Earth's orbit. Some inequalities of time may arise from the eccentricities of the orbs of the satellites; but those cannot answer in all the satellites, and at all times to the position and distance of the Earth from the Sun.

The mean motions of Jupiter's satellites is also swifter in his descent from his aphelium to his perihelium, than in his ascent in the other half of his orb: But this inequality has no respect to the position of the Earth, and in the three interior satellites is insensibie, as I find by computation from the theory of their gravity." —Prop. XI., Book II., Part III, p. 77-78.

These passages show how open Newton's mind was to new suggestions, and how willingly he recognized all contemporaneous discoveries. T. J. J. SEE.

Aurora Borealis at Lancaster, N. H.—On August 21st, 1903, while at Lancaster, N. H., I had the pleasure of witnessing a very interesting, if not remarkable, display of the Northern Lights, or Aurora Borealis. The sky was clear with the exception of a few clouds near the northern horizon. Soon after dark streamers rose from the northern horizon, between the N.E. and N.W. points, glowing and fading in the usual manner, and giving a white light similar to that of the Milky Way. Most of the streamer reached the zenith, and some passed beyond it. At ten minutes past nine o'clock a slender streamer arose directly in the east, passed about ten degrees south of the zenith, and descended to the western horizon. Soon after the western end of the streamer opened out like a feather, and a few minutes later closed up and the eastern end opened out in the same manner. The eastern end did not close up but instead split into fifteen or twenty cross sections, like so many comet tails, each one pointing toward the zenith. These streaks were from three to six degrees long, and from one-half to two degrees wide, and remained visible for fifteen or twenty minutes.

CLARENCE W. CARLISLE.

SOMERVILLE, Mass.

Time and Its Measurement by F. R. Moulton of the University of Chicago is presented very well, in a brief article in the *Journal of Geography* for September. This article does not speak of the efforts of the Western Union Telegraph Company and the New York Self-Winding Clock Company to drive all the Observatories, but the United States Naval Observatory, out of the railroad service, so that the telegraph company might have the pay for all railroad time and the Self-Winding Clock Company might sell their clocks to all railroads which would want them in connection with the use of the Washington time. A three-cornered deal in which $30,000 was involved would now be interesting matter for public investigation.

Cycles of Eclipses is an illustrated paper in *Knowledge* (English) by A. C. D. Crommelin, which presents the theme in a comprehensive way by a careful study of cycles for the solar eclipses for a period of more than 75 years. The tables, graphic paths and other useful data are brought together in an interesting and helpful way.

William Gaertner & Company.—While in Chicago recently we visited the shops of William Gaertner & Company and of O. L. Petitdidier. The increased capacity of their shops and the amount of work in hand waiting for them to do was a pleasant surprise to us. These skilled makers of scientific instruments already have a deserved reputation as among the best in this country.

At Mr. Gaertner's shop we were astonished to see parts of a photographic measuring machine in process of making that appeared to be planned for a variety of work that we did not know was being attempted anywhere in this

country. This line of work is quite new for Mr. Gaertner but he has already made two such machines for prominent astronomers in large observatories, that we have heard give entire satisfaction. It is no easy task to construct a photographic measuring machine that will handle a 10x12-inch plate conveniently, rapidly and accurately. Astronomers of the United States have been depending on foreign makers for such machines in the past, and the expense of them so procured has been large. Mr. Gaertner appears to do just as good work for little more than half the cost to the purchaser.

The optical work by Petitdidier needs no words of commendation from us, it is known to be of the best done anywhere.

The Precession of the Equinoxes.

"Precession of the Equinoxes! What do they precede?"
Said someone to someone else who answered him with speed,
"Each equinox precedes the one that came a year before,"
And then waxed wroth because there rose a great derisive roar.

"I tell you all," he stoutly said, and sternly looked about,
"This thing you're pleased to ridicule is true beyond a doubt.
And though you laugh so loudly, I asseverate once more,
Each equinox precedes the one that came a year before."

—M. H. SIMPSON.

Publications of the Lick Observatory, Vol. VI, 1903.—This volume of about 400 pages includes the following separate schemes of astronomical work:

The declinations of the Bethlehem latitude stars.
Additional standard close circumpolar stars.
Zodiacal stars for heliometer measures of the major planets.
The southern stars of the catalogue of Piazzi.
The reference stars for the photographs of Eros.
Miscellaneous observations, including those of Eros, Nova Persei, comets and comparison stars.

In all there are included about 11,700 full observations and 2,700 observations in only one coördinate, for the determination of 4500 stars.

Richard H. Tucker, astronomer in the Lick Observatory has been in charge of this work, and it was completed in May 1902 and has been since published and distributed.

The Sun's Heat Given Out by Contraction.—One of the good books written in 1901 by Sir Robert S. Ball, in untechnical language is "The Earth's Beginning." In the appendix are a few sections giving the mode of reaching some of the astronomical results that interest all readers, and the methods of obtaining them which will especially interest those having enough knowledge of the mathematics to follow the calculations. In one of these sections is found a mathematical expression for the Sun's heat given out by contraction. Two conclusions are reached which we give in the words of the author, as follows:

"The energy liberated in the contraction of the Sun from infinity to its present dimensions would, if turned into heat, suffice to raise 47,000,000 globes of water each having the same mass as the Sun through one degree Fahr."

"The energy liberated in the contraction of the Sun from infinity to its present dimensions, is as great as would be produced by the combustion of 3,400 globes of coal each as heavy as the Sun."

Physicists now sometimes call 3,400, in such a case, a coal unit.

BOOK NOTICE.

The Solar System is a new book of 134 pages by Percival Lowell that will interest all readers desiring late knowledge of the astronomy of the solar system, told in a direct and a scientifically correct way.

It is published by Houghton, Mifflin and Company, is 12 mo. in size and its cost is $1.25. The work of the printer is neat and attractive, having marginal titles to paragraphs in red ink.

The plan of the book is unique. It begins by giving the position of the solar system in space and in knowledge, its constituents and a statement of some of the obsolete views regarding it that now form merely a part of its history.

The community of interest of the members of the solar system is seen in the character of their paths around the Sun. Illustrations of the orbits of the inner planets and those of the outer group are drawn to scale showing the elliptical character, and the perihelion point of each orbit distinctly marked. The path of the new planet Eros is in place, with its period marked as 643 days and a longitude of perihelion at 121°, which point is only 21° eastward from the similar point in the Earth's path around the Sun. This plainly shows what a near approach the planet Eros makes to the Earth when the two bodies are passing in the vicinity of these points at the same time. This is also why Eros is so useful in the study of parallax now going on in many of the principal observatories of the world.

As we look at the proof of the equation:

$$v^2 = \mu\left(\frac{2}{r} \pm \frac{1}{a}\right)$$

we wonder that more of the ordinary college text books do not introduce some such simple proof as the one Mr. Lowell uses, to establish so important a relation as that given by the equation. The inferences to be drawn from such proofs are many and they are easy and certain of comprehension.

Naturally meteors are next considered; their appearance, physical condition temperature, their paths, origin, speed, association with comets, and how comets become meteor-streams. In the study of the orbits of comets considerable late investigation finds place that has bearing on the origin of the comets of large orbits best known to us. We were pleased to find notice of the suggestion of Schiaparelli in 1895, and of the work of Fabry of Marseilles.

From this later study it appears that comets do not behave in their orbits, as they would if the Sun were at rest. More than this the domain of the Sun is so enormously great that comets of very large orbits compared with the orbit of Neptune still come under his powerful sway. We find a neat simple illustration of this important fact on page 23, in which the domain of the Sun is compared to that of α Centauri. The mass of α Centauri considering both components of this double star is twice that of our Sun. Its distance is 275,000 times that of the Sun from the Earth. To find the point of equal attraction between the Sun and α Centauri on a line connecting the two stars:

Let m = mass of Sun.
$2m$ = mass of α Centauri.
d = distance from Sun to point of equal attraction in astronomical units.
a = Distance between Sun and α Centauri. Then

$$\frac{m}{d^2} = \frac{2m}{(a-d)^2}$$

Solving for d, we find it equal to 114,000 astronomical units. Now since Neptune's distance is only 30 astronomical units, it is evident that the Sun will not let comets obey α Centauri in preference to its own attractive power unless they are more than 114,000 time s more distant than the Earth is from it. Readers of the book will notice that the printer possibly has made an error in setting the equation. It should read as we have given it above, and not as it appears on page 23. Mr. Lowell has given the correct result which properly comes from the equation we have used.

The author makes one more reference to the solar system as a whole in speaking of it as having a single central Sun. The inference that other stars in the heavens have planetary systems attending them, as well as our own is both natural and probable. It may be long before this fact can be proved generally, but if it should be so, one important difference is at once realized, namely the planetary systems of other stars which are double or multiple. The mathematical astronomer thinks that his work is hard enough and complex enough when he has to deal with only one central Sun. If a system should have two or more central suns controlling the motions of planets and comets revolving aronnd them, the difficulty of the practical astronomy of such a system would be immensely increased. Our problem of the motion of the Moon in view of the attraction of the Sun and the Earth gives a suggestion of what we mean.

Next, the author considers some of the planets of the solar system separately. The study of the markings on the surface of the planet Mercury began in 1889, by the keen-eyed Schiaparelli of Italy. His conclusion was that the periods of revolution and of rotation were nearly of the same length. Work at Mr. Lowell's Observatory at Flagstaff corroborates that of Schiaparelli. These astronomers claim that the surface markings on this planet are well enough seen to reveal libration which should be expected because its path is an ellipse, and the author finds by computation that the maximum libration in longitude is 23° 40′ 38″. The effect of the tides is also considered in this connection, according to the modern theory of tidal action advanced by Professor G. H. Darwin, and the interesting results from the same as applied to the planets. The consequence is a great retardation in time of rotation on the planet Mercury as compared with the known periods of most of the other planets.

Venus, and Earth as a planet are passed by, and Mars, the planet on which the author has done a large amount of observing work is next considered.

While Mercury is old, the author thinks the color of Mars a conclusive criterion of middle age, and that the planet is a life supporting world, that it has polar regions, temperate zones and tropics, that its seasons are much like our own with days of about the same length as our own and that it has scant atmosphere.

The key to the study of the surface markings of Mars appears to be the changes in the polar caps. Herschel noticed these changes long ago, but Schiaparelli in 1877, by pains-taking study discovered the markings of the surface on Mars we call "canals" to the number of 104. At Flagstaff those that have been mapped are 350 and the author says, "Their number appears to be legion." He speaks of the shaded portions of the planet, formerly thought of as seas, he

thinks, now, are not bodies of water at all, but areas of vegetation. The polar caps are snow, for they show increase and diminution as the season advances to summer and returns to the winter, as would be expected if consisting of snow and ice.

Saturn and its system, Jupiter and his comets, and an article of 17 pages on Cosmogony followed by a table of the elements of the Solar System concludes the book.

This new book gives the latest information on the theme of which it treats.

Erratum.—We would call attention to an error of the copyist which occurs on page 344 June-July number in giving the declinations of stars No. 57 and No. 58. The declination should have been:

Star 57.....$\Delta\delta = +9'.4$
58..... $= -1\ .7$

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